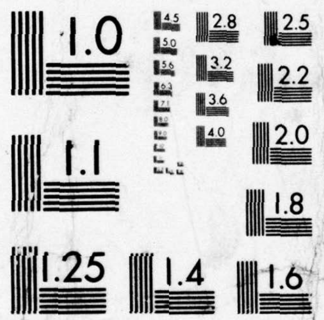
AD-A032 002 ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LAB MOFFE--ETC F/G 1/2
ANNUAL REPORT, FY-75.(U)
1975

UNCLASSIFIED NL

1 OF 1
AD
A032002

END
DATE
FILMED
1-76



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The specific emphases for revision in the FY 76 update of the plan

need for a rational, systematic resource allocation scheme, the AMRDL is continuing an aggressive program to develop a resource

performed by NASA as a non-reimbursable support service for the three collocated directorates who account for practically all 6.1

TABLE OF CONTENTS

APPENDIXES

LIST OF FIGURES

LIST OF TABLES

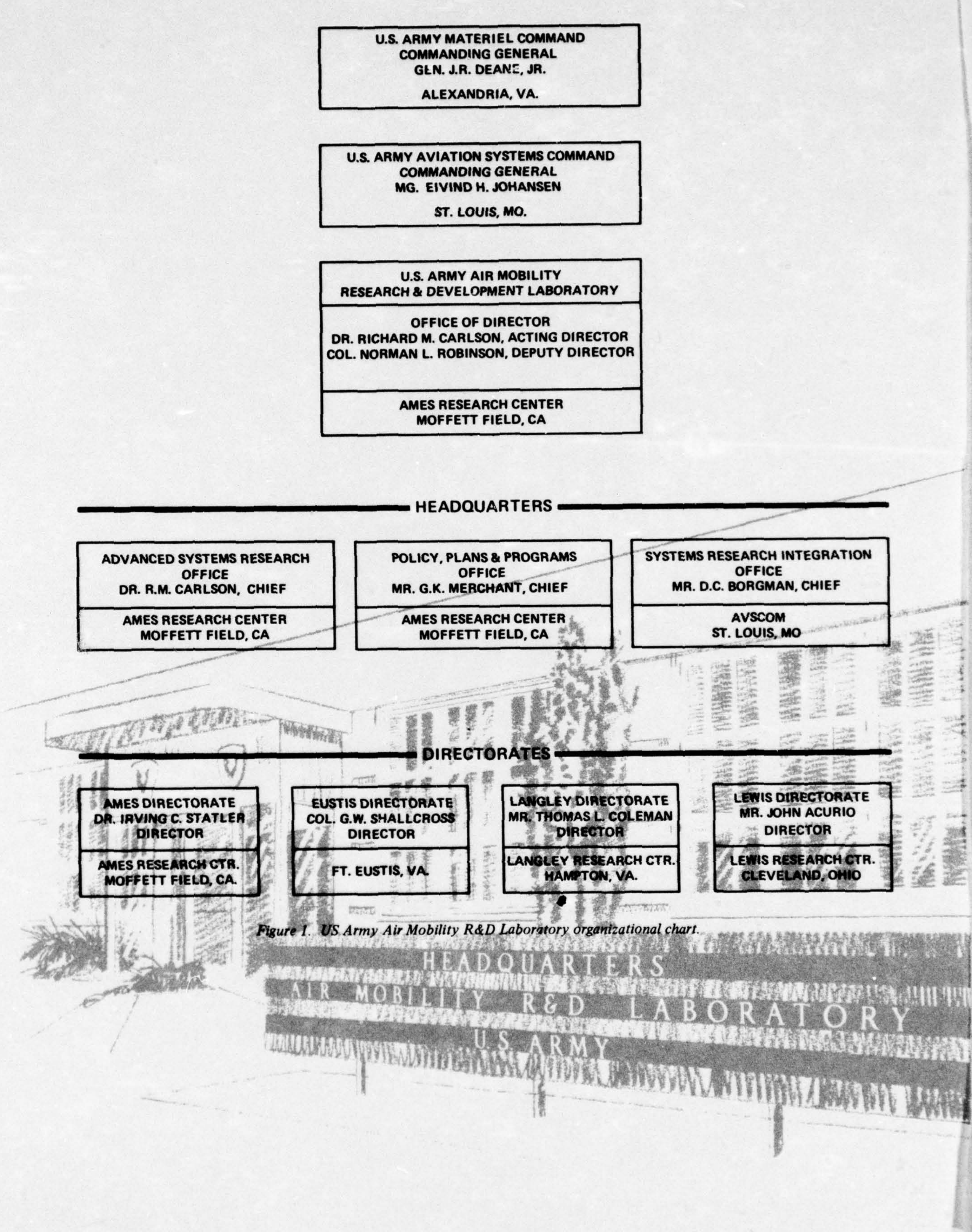


Figure 1. US Army Air Mobility R&D Laboratory organizational chart.

US ARMY AIR MOBILITY R&D LABORATORY
– FY75 REPORT OF ACTIVITIES –

INTRODUCTION

The US Army Air Mobility R&D Laboratory (AMRDL) is the Research and Development Laboratory of the US Army Aviation Systems Command (AVSCOM). The capabilities of its staff of research, engineering, and support personnel span the sciences, disciplines, and technologies of Army aviation. Its organization is represented by the chart (figure 1) located on the opposite page.

The Laboratory is charged with the following mission elements:

- Plan, develop, manage, and execute for the AVSCOM the research and exploratory development programs and the advanced development program through demonstration of technology to provide a strong technical base for future development of superior airmobile systems.
- Manage and direct on a task basis, as assigned by Commander, AVSCOM, tasks in advanced and engineering development subsequent to demonstration of technology.
- Maintain cognizance of, and provide consultative support for, advanced development subsequent to demonstration of technology, engineering development, operational development, and test for all Army airmobile systems.
- Provide technical consultation and independent risk assessment to Commander, AVSCOM for systems and components under development.

The Laboratory strives for improvement in both the acquisition of a technology base and the support to system developers. By establishing and maintaining broad capabilities, the Laboratory has been able to achieve multidisciplinary capabilities to respond to urgent technical requirements of both the immediate and the long-range needs of Army aviation.

The Laboratory has earned an international reputation for the outstanding achievements and abilities of its staff. The honors and awards received by staff members and the contributions they have made to the world's scientific literature during 1975 are listed in this report. Overviews are given for this years accomplishments in the various technical areas to illustrate the scope and purposes of the Laboratory's research and development programs.

During FY 75, AMRDL has operated under a continuing climate of austerity in terms of funds. Realistic assessment of the Laboratory goals relative to the available resources requires a continual adaptation of the Laboratory's program structure to assure short- and long-range research and development efforts are best directed to activities which will achieve the Army objectives for which AVSCOM is responsible.

This FY 75 Annual Laboratory Posture Report is prepared in response to the US Army Materiel Command instructions and guidance contained in letters AMCDMA-ST dated March 31, 1975 and April 30, 1975.

KEY EXECUTIVE ITEMS

NOTEWORTHY MANAGEMENT ITEMS

The most unique aspect of the management of US Army Air Mobility Research and Development Laboratory, lies in its ability to operate as a single operating entity although its four separate Directorates are geographically dispersed from coast to coast. The Laboratory operates under a single Director and is managed as a unit. This unity of management allows for full responsiveness to the needs of the various program managers and it allows the entire capability of the Laboratory to be brought to bear on any specific objective quickly.

For example, quick response by AMRDL, in support of the Remotely Piloted Vehicle (RPV) Weapon Systems Manager at AVSCOM, permitted rapid issuance of a request for proposal and selection of a contractor for the AQUILA RPV program. This urgent and highly visible program is being actively supported by AMRDL through contract monitoring, briefings to Army management, and coordination with TRADOC on AQUILA and the Concept Formulation Package. The AQUILA program is the first Army program to utilize the Letter of Agreement between AMC and TRADOC as the management structure. AMRDL initiated a supporting technology program for RPV's to assure that solutions are developed for high risk component/operational areas such as propulsion system, survivability, and launch and recovery.

In another area of management, the vigorous liaison program between AMRDL and the user of Army aircraft has been maintained. Frequent contacts have been held with the US Army Training and Doctrine Command (TRADOC) and the US Army Forces Command (FORSCOM). These actions have been expanded into three separate formal actions; Troop Visitation Program, AMC Engineer Field Visit Program, and AMRDL/TRADOC Liaison Program.

Troop Visitation Program – This program was established in response to a letter from the AMC Deputy for Laboratories in 1974 and was implemented by AMRDL personnel participation in Operation Jack Frost, conducted in Alaska; Operation Gallant Shield at Fort Bliss, Texas; and visits to the 1st Air Cavalry Division, Fort Hood, Texas, and the 121st Aviation Company, Fort Benning, Georgia.

AMC Field Engineer Program – This program was established in FY 75 in response to a letter by General Vaughan, AMC, and consists of individual engineers visiting a unit for a period of 30 day. AMRDL participated in FY 75 by sending one civilian engineer to the 9th Division, Fort Lewis, Washington, during the Gallant Shield Operation.

AMRDL/TRADOC Liaison Program – This is an ongoing program established in 1974. During FY 75, 32 on-site visits with TRADOC activities were made by AMRDL personnel. At least two

trips to each TRADOC School/Center and numerous briefings with TRADOC Headquarters were conducted during the fiscal year.

Acting in response to a need of the COBRA P.M., AMRDL in a very rapid response prepared the RFP for and played a major role in the evaluation process of selecting a contractor to develop improved rotor blades for the AH-1Q. The goals are to provide blades incorporating latest airfoil technology and changes in rotor blade geometry to provide increased aircraft performance, while providing rotor blades with significantly improved structural and service life characteristics.

Project Inspect was evolved as a management technique using analytical procedures to set up inspection schedules for Army helicopters. Presently six UH-1 companies at Fort Campbell are being utilized in an evaluation of this inspection concept. It is anticipated that a 25% reduction in maintenance man hours and a 10% increase in aircraft readiness will be demonstrated utilizing these procedures.

The Laboratory was presented with an Award for Excellence by AMC for gaining international recognition as an outstanding organization during the past year, with "unquestionable expertise in the areas of helicopter technology and operations." The Laboratory was also cited for its successful implementation of the development of three new Army helicopter programs. AMRDL's performance was judged on its contributions within mission assignments to the Army's capability and readiness during the previous year. The citation described the Laboratory as AMC's primary source of expertise on aircraft aeronautics, and the principal Department of Defense agency for small gas-turbine technology. AMRDL was one of two AMC laboratories to receive this honor.

NOTEWORTHY TECHNICAL ITEMS

Because of the vital importance of the air flow field of a rotor to the satisfactory operation of the helicopter, this 6.2 aerodynamics technology area was designated at the AMRDL Innovative Program for 1975. A rotor blade is required to produce a nearly constant lifting moment while operating over a wide range of velocities and angles of attack. It is extremely difficult to effectively measure these parameters on a rotating blade in flight. To study these actions, analytical simulations were made followed by mechanical simulation of a pitching airfoil in the wind tunnel. The results of these programs have provided a comprehension never before available and have already been effectively used in the development of improved rotor airfoil characteristics.

Flight tests of an instrumented UH-1H helicopter in Alaska revealed that the rotor loads and stresses are substantially higher when the aircraft is operated in cold weather conditions. The significantly increased air density and low temperature, lead to markedly increased turbine power and rotor performance capabilities. Because of this, it can be expected that the aircraft may be flown using this increased capability and hence the loadings would logically be expected to be greater. These results imply that the fatigue life of critical components may be foreshortened if the aircraft are used in extremely cold weather conditions without some precautions taken to minimize the inadvertant overloads.

Environmental considerations, although not identified as a Major AMC Thrust, are a prime Laboratory objective. A program to reduce emission levels of turbine combustors led to two combustor concepts which have demonstrated by engine testing a 50 percent reduction in emissions. Investigation of the character of high speed helicopter impulsive noise led to the finding that for the UH-1H, the strongest acoustic wave is a negative (rarefaction) pressure pulse which dominates the acoustic signature. This finding is expected to directly affect the course of future acoustic studies.

Specific research emphasis has been placed on the development of a simulation capability for Low Level Night Operations (LLNO) and Nap-of-the-earth (NOE) helicopter flight. Existing simulators have been modified to use terrain boards having a representation of Hunter Liggett Military Reservation. Pilot evaluations of the simulation are continuing.

A small 4.7 inch diameter scale model of a proven 33 inch diameter axial flow compressor stage was tested and found to produce results that were close to those of the full scale machine. The test demonstrates that data on large compressors are applicable to a much smaller scale than was previously thought to possible. A wide data base is now available for use in designing improved small compressors with the potential of a large savings in development cost.

A fully instrumented rotor blade for the AH-1 was fabricated and flight tested. Three hundred measurement gages including those for strain and pressure were mounted on the blade. Flight test data obtained will provide comprehensive information on the detailed nature of blade loading and the stress and vibration of the blade in response to these loadings. These results will provide a data base heretofore unattainable.

A full scale all composite tail cone for the AH-1G helicopter was fabricated using carbon as the primary structural material. The tail cone has undergone an extensive development program including verification of fatigue and dynamic characteristics. The tail cone, installed and integrated into the airframe, offers the potential of a 20% savings in weight and a 20% savings in life cycle cost.

An instrumented CH-47 was dropped from the NASA Lunar Lander Facility at Langley Field to simulate a 50 ft/sec ground contact speed. The objective of this test is to obtain safety and survivability data for Army helicopters and to correlate the results with the AMRDL developed KRASH analytical program data. Impressive correlation has been achieved between the analytical program and test results. This lends credence to the use of the KRASH program in the design and evaluation of new helicopters crashworthiness.

The XV-15 Tilt Rotor Research Aircraft completed the Design Phase in December, 1974. Fabrication of the fuselage and most of the major components is completed and development testing is in process. This joint Army/NASA effort will lead to full technical demonstration of the tilt-rotor concept of providing an aircraft with good hover capability while greatly increasing productivity at reduced fuel usage.

The Advancing Blade Concept (ABC) aircraft, following an August, 1973, accident attributed to a rotor inflow induced control problem, has received a modified flight control system. A flight test program has been initiated to evaluate the corrective measures obtained from analysis and model tests. Flight tests were initiated with modified flight controls on 21 July 1975.

PROGRAM STRUCTURE

The interest of the Army in utilizing the air space has added another dimension to the battlefield for the land combat functions of mobility, intelligence, firepower, combat service support, and command, control and communications. The current and projected airmobile systems that are intended to perform these functions are shown in Figure 2 and includes a matrix indicating possible system replacements.

LAND COMBAT FUNCTION	OPERATIONAL SYSTEMS	REPLACEMENT SYSTEMS									
		AAH	UTTAS	HLH	ASH	STARS-V	RPV	LTTAS	MAVS	VHLH	AAWS
MOBILITY	UH-1		■								
	CH-47							▨			
	CH-54			■							
										▨	
INTELLIGENCE	LOH				■						
	OV-1D						■		▨		
FIREPOWER	UH-1	■									▨
	AH-1	■									▨
COMBAT SERVICE SUPPORT	UH-1		■								
	CH-47							▨			
	CH-54			■							
										▨	
COMMAND, CONTROL AND COMMUNICATION	LOH					▨					
	UH-1		■								

■ DEVELOPING
▨ PROJECTED SYSTEMS (NOT APPROVED BY DA)

Figure 2. System designations and replacement plan for land combat functions.

The Army's avaiation needs, represented by the projected aircraft system and conceptual requirements, have been analyzed to define gaps in technology. The R&D program structure must reflect, not only the response to the currently projected capability requirements, but also, the need for a technological base that will fill these gaps and will stimulate innovative and imaginative airmobile missions functions, and concepts.

The R&D program of this Laboratory provides the technological base required for fielding these systems with significant improvements over current aircraft in survivability, reliability, maintainability, durability, and operational performance and effectiveness. At the same time the program responds to AMC objectives, major thrusts, and priorities; all within R&D funding limitations.

To maintain and expand the technological base required in the development of advanced airmobile systems, the Laboratory formulates a coordinated program of research, exploratory development, and advanced development in the basic sciences, basic and supporting technologies, and advanced subsystems and technology demonstration. A life-cycle representation of this program structure relating to AMRDL's technologies and disciplines is shown in figure 3.

The Laboratory has prepared the fourth (FY 76) edition of the Army Aviation Research, Development, Test, and Engineering (RDT&E) Plan. The Plan is AVSCOM's response to the requirement for a Consolidated R&D Plan and addresses the near-and long-term RDT&E activities that are required for achieving the Army objectives and material needs for which AVSCOM is responsible. This plan presents a time-phased analysis and presentation of the scientific and technological programs that are required for the development of advanced airmobile systems. It is the purpose of this document to set forth plans and objectives for Army aviation research and development activities for the FY 76-95 period, with particular emphasis on the period from the present to FY 80. It presents, quantitatively, the relationship between the current technological base and future requirements, while taking into account the potential impact of advances in fundamental technologies.

The Laboratory's actual R&D program for FY 75 was consistent with the goals and objectives defined in the Army Aviation RDT&E Plan and was oriented, to the maximum extent possible, in the directions of AMC goals, R&D thrusts, and objectives for FY 75, and the Army-User Goals established by DCSOPS. The AMC Management by Objectives (MBO) goals applicable to AMRDL R&D efforts and AMC Major R&D Thrusts are presented in figure 4, aligned with AMRDL technical R&D project structure. Where necessary, R&D activity has been redirected, terminated, or shifted to meet changing critical areas of need; for example, continuing support of the RPV and NOE programs and redirection of the advanced research rotor concepts program to discontinue the original plan of a completely versatile rotor system in favor of several substantially simpler rotors.

The AMC Major Thrusts define express, not exclusive, interests, and so neither the RDT&E Plan nor the Laboratory's program was limited solely to the Major Thrusts. While most of the Laboratory's efforts have a relationship to the Major Thrusts, the major emphasis is the reduction of life-cycle costs. Thus, such areas are emphasized as: reduced vibratory loads for longer life of dynamic components; improved survivability; increased reliability of propulsion and drive-train components; reduced vulnerability of transmission systems; the use of composities for rotor blades; and new rotor concepts for improved performance and, hence, increased productivity, agility, and survivability. Specific emphasis has been placed on research to improve aircraft night operation, particularly at low level (LLNO). There are two critical aircraft roles, scout and attack, which require LLNO, but all systems will require this capability when operating in the forward portion of the battle area.

The Requirements Directorate of DCSOPS has provided guidance for the DA Technology Base in the form of prioritized goals (noted above) which represent the operational requirements of the future. This listing was followed by the Laboratory as well as the guidelines provided by the Assistant Secretary of Army (Research and Development) entitled "Peacetime R&D Strategy" for the prioritizing of the Laboratory's R&D programs with subsequent funding application. The Contents of the "Peacetime R&D Strategy" are contained in Appendix A.

While the RDT&E Plan establishes the basis for programming, it is not in itself a program. With the application of funds, programming can be accomplished. The distribution of AMRDL FY 75 direct funds by program category is shown in figure 5. This distribution applies only to AMRDL and should not be construed as the total distribution of R&D funds for Army aviation.

The distribution of funds as applied to the Laboratory's six main technological disciplines, to the Aircraft Systems Synthesis Project, and to Advanced Technology Demonstration is included in the R&D program flow diagrams of Appendix B. The

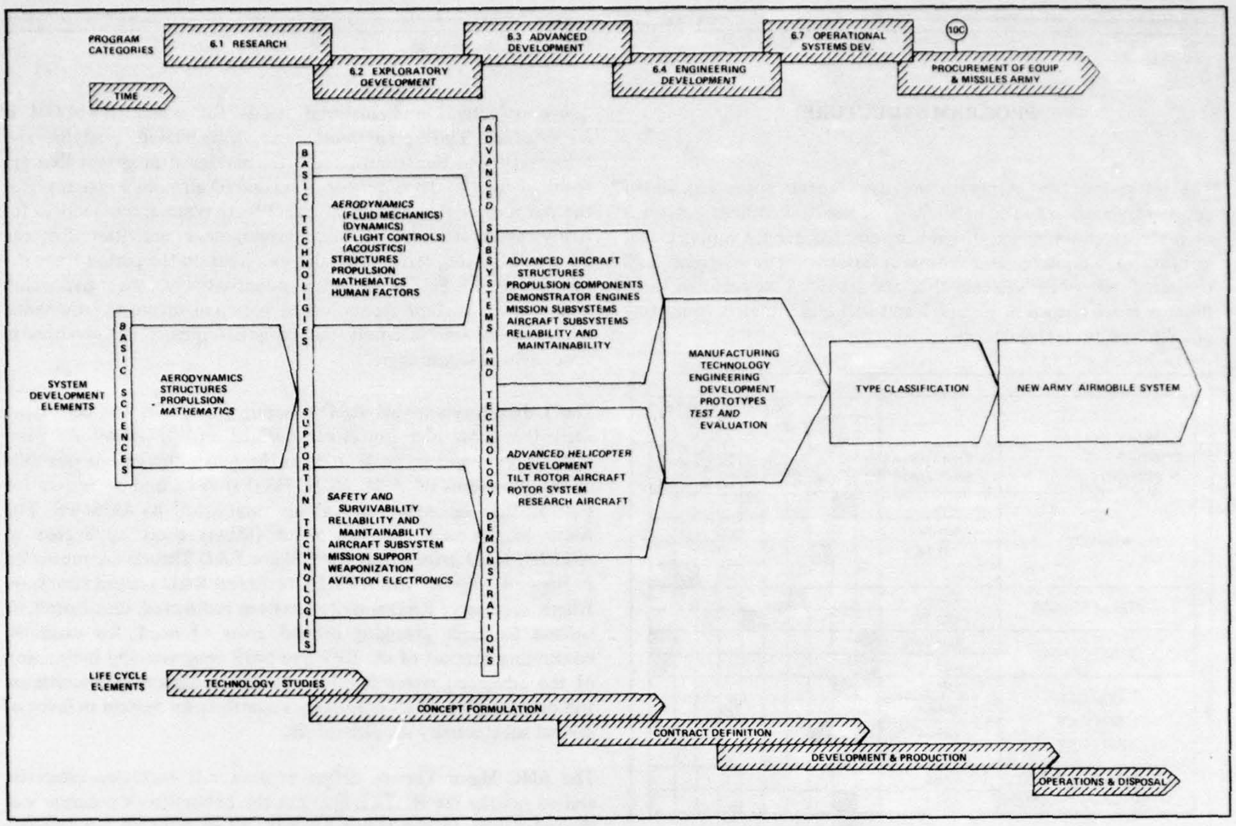


Figure 3. Relationship of technologies for new airmobile systems.

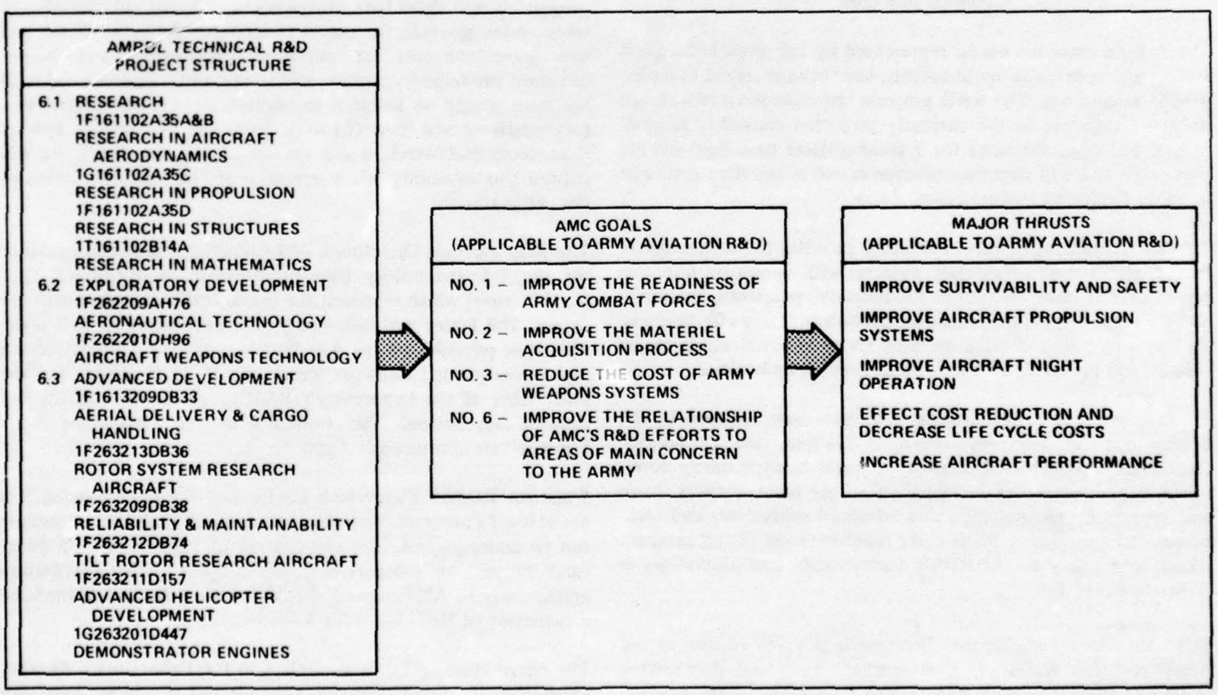


Figure 4. AMRDL technical projects aligned with AMC R&D goals and major thrusts.

distribution by program category shown in figure 5 does not include 6.4 activities which are primarily the responsibility of the Directorate for Research, Development and Engineering, AVSCOM. This Laboratory does not have any 6.7 category programs (Operational Systems).

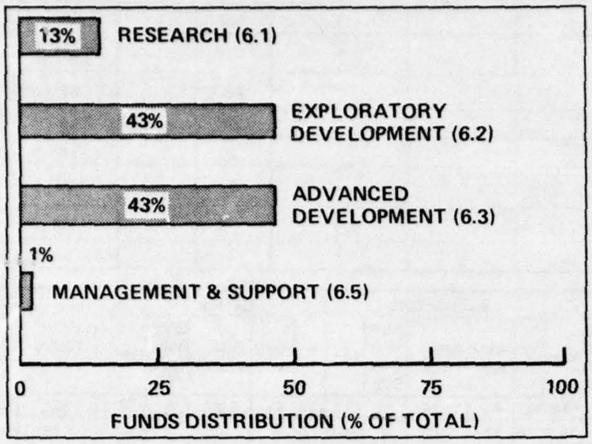


Figure 5. AMRDL direct funds distribution by program category.

The small amount ($590,000 or 1%) spent on management and support (6.5 program category) consists of expenditures for operation of AMRDL at Ames Research Center ($450,000), operation of a West Coast Technical Industrial Liaison Office ($70,000) at Pasadena, CA, and special purpose equipment and minor construction ($70,000) at the Eustis Directorate. However, Headquarters, AMRDL, located at Ames Research Center, is not charged for the support services provided by NASA. This is another example of improving the effectiveness of resource utilization on a national basis as stated in a previous paragraph.

The potential detrimental impact of average grade roll back and flat funding levels, together with the desire to maintain a relatively stable in-house to out-of-house ratio on program balance has been addressed in the Personnel and Manpower section. These factors will continue to draw deliberate management attention in order to maintain a balanced program of in-house and contracted effort, without jeopardizing the Army's air mobility R&D capability, its technical output, or the human resources which are the keystone of this Laboratory.

A critical factor to which Laboratory management continues to divert special attention is the utilization of technology. The question is, "what is the most logical method by which the technology evolved by the Laboratory – whether in-house jointly with NASA, or under contract with industry – can be transferred into the industrial base and into the present and future operating airmobile fleets?". This question has perpetually confronted all military R&D agencies and remains a challenge for all military R&D managers as evidenced by the presentation by MG Stewart C. Meyer at the AMC-Industry meeting in Atlanta, Georgia on 30-31 May 1974. The management of this Laboratory will continue to meet this challenge, and seek every means possible to ensure that the technology transfer does take place. A major step was taken in this direction through a presentation made at the American Defense Preparedness Association Executive Symposium on Army Aviation Systems Management by Laboratory Director Mr. Paul Yaggy on 8 October 1974. It is futher supported by numerous joint Industry/AMRDL technology briefings and by AMRDL efforts in support of the recently established AMC Technical Industrial Liaison Office on the West Coast.

PERSONNEL AND MANPOWER

Professional and engineer/scientist position vacancies have been filled with highly qualified personnel through a recent intensive recruiting campaign. The judicious use of Project REFLEX authority, and the management of manpower by matching funds to workload, allowed the Laboratory to stay within the personnel constraints imposed by the fiscal year's funds allocation. REFLEX authority permits scientist-managers the flexibility to adjust manpower based on available monetary resources and workload without manpower surveys. The Laboratory fully endorses the REFLEX concept for efficient management. The Army Air Mobility R&D Laboratory was among those specifically commended by the General Accounting Office as a successful REFLEX venture.

From a total of 589 employees in 1971, the Laboratory stength increased to 604 in FY 72, but has now decreased to 562. The military complement decreased from a high in FY 71 of 54 to the present level of 27 (figure 6).

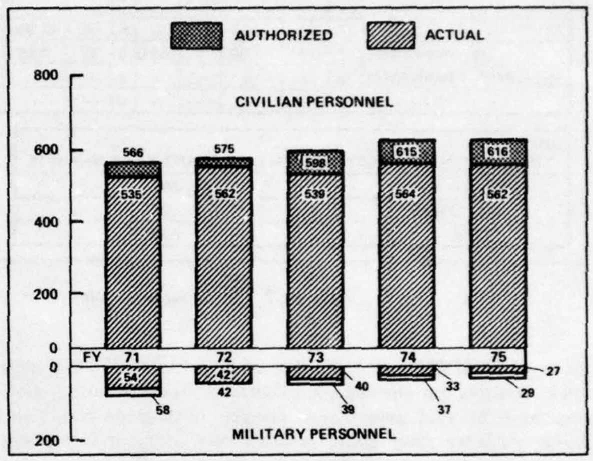


Figure 6. Personnel distribution – FY 71-75.

The AMRDL is intentionally staffed in a very spartan manner to minimize overhead. As a result, it enjoys a very high ratio of professional-to-support personnel, which is partly due to the nature of its mission and partly to the unique provisions for support under the terms of the joint Army-NASA agreement. In addition, advantage is taken of automated support wherever possible to aid in maintaining this high ratio. Breakdown of work force strength in personnel and distribution of man-years of effort as of 30 June 1975 is shown in figure 7.

Project Reflex – Since its inception in 1970, this Laboratory has operated under REFLEX management. The authority thereby granted the Laboratory Director greatly simplified the task of establishing proper manning levels for the new organization, and conserved resources that otherwise would have been required for manpower surveys and organizational studies. The Laboratory Director has given each subordinate Director and Office Chief the authority over his resources within the regulatory and administrative limitations imposed by higher headquarters. REFLEX implies the correlation of R&D level-of-effort with dollar resources without the intervention of other arbitrary control devices; however, this has not entirely been the case with this Laboratory. Progress has been made this year with average grade ceilings not being imposed directly on the Laboratory although the Laboratory's average grade continues to impact on the average

(A) DISTRIBUTION OF MANYEARS OF EFFORT AS OF 30 JUN 75	ARMY								ALL OTHER APPROP	TOTAL ALL SOURCES
	RDTE			PROCUREMENT SUPPORTED DIRECTLY OR INDIRECTLY BY		OMA		TOTAL ALL APPROP		
	HQ AMC	OTHER AMC	NON-AMC	AMC	NON-AMC	AMC	NON-AMC			
CIVILIAN PERSONNEL TOTAL		562						562		562
TECHNICAL TOTAL (PROF & TECHNICIAN)		321						321		321
ADMINISTRATIVE TOTAL		241						241		241
SUPPORT & G & A TOTAL		–						–		–
MILITARY PERSONNEL TOTAL		27						27		27
TECHNICAL TOTAL (PROF & TECHNICIAN)		21						21		21
ADMINISTRATIVE TOTAL		6						6		6
SUPPORT & G & A TOTAL		–						–		–

(B) PROFILE OF TECHNICAL PERSONNEL SKILLS LEVELS	DOCTORS					MASTERS					BACHELORS					OTHER					TOTAL #
	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	#	AVG AGE	AVG GRADE	AVG YRS GVT SVC	%**	
CIVILIAN	27	35	12.96	5	0	69	35	12.38	9	+7.8	152	40	12.16	12	-3.2	73	41	8.92	15	-38.1	321
MILITARY OFCRS(01-010)	1	27	2.00	–	-50.0	9	39	4.56	–	-10.0	6	32	3.00	–	+20.0	0	–	–	–	–	16
MILITARY WO(W1-W4)	0	–	–	–	–	0	–	–	–	–	0	–	–	–	–	2	44	3.50	–	+100.0	2
MILITARY EM(E1-E9)	0	–	–	–	–	0	–	–	–	–	0	–	–	–	–	3	27	5.67	–	-50.0	3

(C) WORKFORCE STRENGTH IN PEOPLE ON BOARD AS OF 30 JUN 75	
CIVILIAN	562
MILITARY	27
TOTAL	589

**PERCENT CHANGE (+/-) SINCE FY 74 IN NUMBER (#) ONLY.

Figure 7. Distribution of Man-Years of effort for AMRDL as of 30 June 1975.

grade of. AVSCOM and AMC. The elimination of direct average grade controls has allowed the Laboratory to utilize other, more responsive internal management criteria. Total grade points and dollar guidance have good, positive correlation and excellent potential for use in monitoring manpower resources.

The initial Project REFLEX implementation phase has proven to be fully successful. However, relaxation of some remaining controls is desirable. Among the more detrimental are: higher authority approval of TDA's and Manpower Utilization and Requirements Report. These controls do not allow the Directors the full freedom of operation for which Project REFLEX was designed.

Military Manpower Resources – The current authorized military strength is 29 (figure 6) which is a reduction of 50% since 1971 and a 22% reduction in the last year. Part of this reduction was the elimination of all military Deputy Director positions at the Directorate level. A continuation of the current military reduction trend will restrict the military/civilian engineering interface required for the development of a strong technology base as well as Army airmobile systems. This military/civilian interface, most important in developing systems to meet the user's needs, has required an increased military liaison effort with TRADOC and FORSCOM.

Civilian Manpower Resources – The current authorized civilian strength for the AMRDL is 616 positions. Many vacancies currently exist, and it remains difficult to fully staff the Laboratory because of the shortage of qualified personnel in certain disciplines, coupled with a deliberate policy to selectively hire only people of high potential. Men and women with outstanding qualifications in engineering, especially those with rotary-wing aircraft experience, are in short supply. For example, it required over 2 years and considerable effort to obtain a qualified rotary-wing engineer for the ASRO position of Aerospace Engineer-Aerodynamics.

Industrial salaries and fringe benefits are such that many qualified candidates are reluctant to leave their positions for government employment. Understlotting for many positions with target levels for advancement has been done deliberately to attract and hold young, talented personnel. Past average grade policies have restricted promotion of young professional employees and if continued may make it difficult to retain these highly trained professionals. Youth is an important factor in any successful organization; AMRDL has an average of only 38 years and strives to continue to attract and hold young researchers and administrative personnel. Less than 4 percent of the work-force are eligible for retirement.

This rise in manpower and contract costs, coupled with a level or decreasing funding profile raises concern over Laboratory program balance. It is the Laboratory policy to maintain an approximate ratio of one dollar for in-house effort to two dollars for out-of-house effort. With a relatively fixed dollar budget, wage increases for Laboratory personnel due to inflation impair the ability to maintain this ratio. This may make it necessary, for example, to weigh the possible loss of some key research engineers and scientists against the possible elimination of some key areas of Laboratory capability to preserve an effective balance of effort.

The Laboratory is rigorously continuing its previously developed and commended EEO Affirmative Plan of Action, as well as for the ancillary plan for Upward Mobility and programs for Spanish-surnamed community members, Federal Women, and correction of Alcohol and Drug Abuse.

ORGANIZATIONAL CONFIGURATION AND MANAGEMENT IMPROVEMENTS

The US Army Air Mobility R&D Laboratory was established in 1970 as an integrated organization with four operating Directorates, as shown in figure 1 (opposite page 1). The Laboratory is assigned to the US Army Aviation Systems Command.

The concept of operations established for the Laboratory emphasizes the following:

- Ensure that a balanced total AMRDL R&D program is established and achieved;
- Increase the effectiveness of support to product developers to ensure improvements in their airmobile systems;
- Provide means for assuring an orderly continuity of efforts from research through exploratory development to demonstration of technology and transfer of knowledge to developers for application.

A management team, composed of the senior managers of the Laboratory, assists the Director in assuring that effective utilization is made of resources for successful mission accomplishment.

The Laboratory management directs its activities to achieve balance between the development and demonstration of technology and the requirement for support of specific airmobile systems concepts. All four of the subordinate Directorates are totally involved in all aspects of the Laboratory mission; however, specific emphasis is given to particular disciplines in each of the Directorates. For example, in the three Directorates collocated with NASA, the largest part of the effort is directed toward research and exploratory development to increase knowledge in the physical and behavioral sciences. Such efforts may, in some cases, be oriented toward recognized operational objectives but may not relate directly to a specific system. Conversely, the primary mission of the Eustis Directorate is in the areas of technological application, military operations technology, and technical support to systems developers. The Eustis Directorate plays a major role in the transfer of technology to industry and the Army users.

At each of the three NASA-collocated Directorates, there is an Army Aeronautical Research Group directly under the operational control of the Director of that Directorate. There is also a Joint Aeronautical Research Group that consists of Army employees working side by side with NASA employees under operational control of NASA supervisors. The efforts of this group are on a broader scope, pursuing mutual interests of both agencies. A Technical Support Group, which consists of a limited number of support professionals and technicians under NASA operational management, provides support to the Army.

The support functions for the three Directorates collocated with NASA Research Centers are largely provided through negotiations with NASA resulting in a minimum allotment of Army resources. Technical support is negotiated by the Director and includes NASA shop capabilities, graphics and reproduction, library and document facilities, computing facilities and specialist's laboratory and calibration functions. Similarly, administrative support is provided in terms of procurement, fiscal and accounting, travel, and other associated services. Monetary resources are supplied to NASA on a reimbursable authority. Program authority is exercised over Army resources by the Laboratory through allocation of program resources against a stipulated plan. Effectiveness and conformance are judged by audit procedures. A limited in-house administrative capability is provided in each of these Directorates to monitor the administrative support services, prepare programs, and perform necessary regulatory functions.

A comparable support function by Army personnel exists at the Eustis Directorate. A Contracting Division, a Legal Division, a Technical Support Division, and an Administrative Support Division report directly to the Director, Eustis Directorate. The Contracting and Legal Divisions are total Laboratory resources and, at the discretion of the Laboratory Director, service other Directorates as required; such instances would occur, for example, when an Army awarded contract is dictated rather than a NASA contract.

The Laboratory Director controls, through the Headquarter's Policy, Plans, and Programs Office, the use of all money resources against approved documents. The authority to contract, delegated to the Director, AMRDL, is redelegated to the Director, Eustis Directorate, who exercises this authority against approved program through the contracting division located at Eustis. Funds supplied to NASA for contract are controlled by the Directors of the Directorates against a program approved by the Director, AMRDL.

Throughout the Laboratory, the concept of vertical alignment is applied to reduce administrative burden and to provide maximum flexibility in the use of technical manpower against continually varying technical emphasis. Vertical alignment provides the ability to readily shift the staff of the Laboratory without detailing, including the mix of specialties and grade levels, in response to the current need, rather than in conformance to an arbitrary organization. Vertical alignment contributes greatly to increased productivity, reduces requirements for services from supporting organizations, and has demonstrated its value in increased responsiveness to customer needs. The flexibilities afforded under REFLEX are significant to satisfactory implementation of this concept.

Integration of Army aviation R&D capability into AMRDL as a single operating unit has resulted in more effective resource utilization and program responsiveness than was possible with the previous separate research and development organizations. It has provided a management structure with maximum flexibility in the utilization of manpower resources and has established a single point of contact for Laboratory assistance to system and product developers. Further integration of Army aviation scientific and engineering capability is warranted and should be pursued. The Laboratory is participating in a Memorandum of Understanding (MOU) arranged between the Army (AMRDL) and the French Office National d'Etudes de Recherches Aerospatiales. Under this management agreement, specific areas of mutual research interest are spelled out, and there is an extensive interchange of research information. Research engineers from France work within the Laboratory and AMRDL engineers work in France on rotational assignments. Extremely complex problems, such as dynamic stall of rotor blades, have benefited directly from such a close interchange.

PLANNING

The Army Aviation RDT&E Plan provides the basis for the Laboratory's program planning. The RDT&E Plan addresses the plans and objectives for Army Aviation R&D activities for the next 20-year period, with particular emphasis on the near-term 5-year period. It relates, in a quantitative manner, the current technological base to the projected future requirements.

The specific emphases for revision in the FY 76 update of the plan were (July 1975 publication date):

- Restate Major Thrusts for FY 76.
- Align programs with AMC goals and guidelines.
- Reappraise all near- and far-term objectives with respect to program completions or realignment.
- Update status of all Army aircraft systems discussed in the Plan.
- Update required resources based on latest program objectives.
- Realign technology sections in accordance with AMRDL R&D Program Data Sheet projects.
- Include a technology annex section to provide project description and near-term objectives.
- Continue publication of an unclassified edition of the Plan for use by the aviation community.

The Plan seeks to explore all viable options for future systems with the goal of providing a range of choices and a means for selecting candidates for development when required. As the operational dates become more distant, a larger number of options can be pursued and at a more fundamental level of research. The Plan is intended to be a management tool to provide visibility of acknowledged requirements and interdependence of necessary technological achievements. While the Plan establishes the basis for programming, it is not in itself a program. It is not constrained by available resources in its stated objectives and corresponding R&D to implement them.

The Plan focuses RDT&E activities to guide the Army's funds into areas of greatest effectiveness. Thus, R&D effort is directed toward ensuring that the most advanced technology is available for use in near-term projects. For new systems further downstream, the effort is directed toward minimizing technical barriers, optimizing key performance factors, and narrowing the options to the most viable. Plans for development of new systems, technological improvement objectives, plans to reach these objectives, and past trends are described in the document.

Desired capabilities and Initial Operational Capability (IOC) dates for most of the projected airmobile systems were based on currently available documentation. For each of the Army's airmobile systems, the mission, key factors, and salient characteristics that determine its performance requirements are discussed in detail in the Plan. These considerations are summarized in figure 8. The missions and the key performance factors are based on current projections of the Army's aviation needs. Conceptual and design studies are conducted to assess advances in each area of technology with respect to their impact on aircraft systems. Such studies are used to identify those areas that appear to hold the highest potential. Gaps in scientific disciplines or supporting technologies are identified. Such studies constitute a major and continuing function of the Laboratory's Advanced Systems Research Office (ASRO).

During the preparation of the RDT&E Plan, consideration was given to the relevant R&D programs of other Army organizations. In particular, activities are coordinated in the areas of human factors, avionics, ground handling, and weapons where performance requirements necessitate the integration of these factors into the total airmobile system, but where mission responsibility for appropriate R&D is in another commodity command or corporate laboratory. Moreover, the Laboratory recognizes and maintains an interchange with those organizations that have been designated as "Lead Laboratories" and whose charters encompass technologies important to Army aviation. For example, this Laboratory has activities and interests that relate directly to the work in fluidics at Harry Diamond Laboratory, to the materials research at Army Materials and Mechanics Research Center, and to the efforts of US Army Electronics Command's Night Vision Laboratory in night operations. Although the AMRDL does not have a "charter," its mission does, in effect, establish the Laboratory as the "Lead Laboratory" in Army airmobile systems.

SYSTEM	MISSION	KEY PERFORMANCE FACTOR
UTTAS	PRIMARY–SQUAD CARRIER SECONDARY–COMBAT/SERVICE SUPPORT	LOW LIFE CYCLE COST
HLH	RETRIEVAL/COMBAT SERVICE SUPPORT, HEAVY BULKY CARGO	CAPACITY AND PRECISION HOVER
AAH	PRIMARY–DIRECT AERIAL FIRE SUPPORT SECONDARY–AERIAL RECONNAISSANCE, SECURITY AND ESCORT	ACQUIRE/DESTROY TARGETS, SURVIVABILITY
RPV	TARGET INFORMATION/ COMBAT SURVEILLANCE	LOW ACQUISITION COST
ASH	DAY AND NIGHT RECONNAISSANCE	TARGET ACQUISITION AGILITY
STARS-V	PRIMARY–OBSERVATION, VISUAL RECONNAISSANCE, COMMAND/CONTROL SECONDARY–BACKUP MEDICAL EVACUATION, LIGHTWEIGHT COMBAT SERVICE SUPPORT	FORWARD BASE OPERATIONS OPERATION/ MAINTENANCE SIMPLICITY
MAVS	SURVEILLANCE AND TARGET ACQUISITION INTELLIGENCE	ENDURANCE/VTOL
LTTAS	PRIMARY–ALL WEATHER, DAY/ NIGHT COMBAT SERVICE SUPPORT SECONDARY–AERIAL TANKER	PRODUCTIVITY ($/TON MILE)
AAWS	ADVANCED AERIAL WEAPONS SYSTEM SECURITY/ESCORT/EXTENDED RANGE RECONNAISSANCE	ACQUIRE/DESTROY TARGETS, SURVIVABILITY
VHLH	TRANSPORTER OF OUTSIZED ITEMS	EMPTY TO GROSS WEIGHT/FUEL LOAD

Figure 8. Army airmobile systems, missions, and key performance factors.

The RDT&E Plan clearly indicates that VTOL aircraft technology can expect significant advances over the 20-year time frame, which, in turn, can affect the aircraft systems designed in the 1976-1995 time period. The precise magnitude of technological improvement that can be achieved is governed by other than purely technical considerations, of which the most important are the necessary budgetary and schedule constraints.

The Plan becomes the program when the required resources in terms of funds, facilities, and personnel are provided for its implementation. Even if unlimited resources were available, it is not likely that all the efforts would be pursued and all of the goals achieved. Therefore, it would be unrealistic to make an estimate of resource requirements that is based on the development of all the concepts for each of the projected systems. Moreover, the available options and alternatives to perform a given task diminish rapidly with time, so estimates of resource requirements are valid only on a relatively short-term basis. Even more to the point, however, is the fact that there are never enough resources to undertake all of the research projects that optimum planning would indicate; there are generally many more feasible technical alternatives available to solve a particular problem than can be economically supported. Under conditions of limited resources, imposed economics, and prescribed goals, a logical resource allocation methodology is the key to orderly progress. Recognizing the

need for a rational, systematic resource allocation scheme, the AMRDL is continuing an aggressive program to develop a resource allocation model.

The Advanced Systems Research Office of AMRDL, under the Aircraft Systems Synthesis Project, directs the development of the Army Aviation RDT&E Plan and is responsible for the formulation of the resource allocation model.

OUTSIDE/INSIDE EXPENDITURES

The distribution of FY 75 program funds received by AMRDL as presented in Table I is categorized under three basic headings: Industry or Academic, other AMC Labs, and other Government Agencies, for each of the program categories; i.e., 6.1, 6.2, etc. Within each category, the amount for contract (outside) and the total amount for that category are listed. The ratio (percent) of the outside contract amount to total each program category are obtained by subtracting the three contract expenditures from the total.

The contract monies under industry or academic institutions include contracted efforts purchased through NASA procurement in direct support of the in-house research efforts at the three Directorates collocated with NASA Research Centers. In regard to the outside/inside expenditures, Table 1, it is important to note that, of the total expenditures in the 6.1 and 6.2 categories, $11.0 million or 51.0% was spent in-house. On the other hand, of the total RDT&E money only $15.6 million or 35.7% was spent in-house. It is also noted that there is no estimated cost to administer for 6.1 category because the contract administration is performed by NASA as a non-reimbursable support service for the three collocated directorates who account for practically all 6.1 research.

As R&D efforts progress through exploratory development to advanced development, the hardware required to conduct research increases. This results in an increase both in dollar amount and percentage of contracted work, as reflected in the 6.3 category. The largest portion of these projects is contracted by the Contracting Division at the Eustis Directorate. In most of these cases, the in-house operation costs applicable for contract administration is provided in the estimated cost to administer column, Table I.

The policy of the Laboratory has been to maintain a balance of not less than one dollar in-house to two dollars out-of-house work for its entire area of responsibility. This policy does not result from guidelines for constraints from higher level, but rather is considered to be a proper ratio in order to maintain both in-house expertise and responsiveness in the industry that supplies the commodities for the Command. As stated in the previous paragraph, the 6.2 category required more in-house effort as compared to the 6.3 category. In FY 75, 43% of AMRDL direct funds were distributed into the 6.2 category while in FY 74 the ratio was 39%. Justification for contract versus in-house is based upon the most effective use of resources and the best mechanism for accomplishing programs goals. The flexibilities of funding provided by SPEF and management of manning levels under REFLEX remove some of the constraints of outside control in a given case, and permit Laboratory management to make decisions based primarily on the merits of the R&D needs of the Army rather than on artificial constraints.

TABLE I. FY 75 OUTSIDE/INSIDE EXPENDITURES (AS OF 30 JUNE 1975)

TOTAL LAB EFFORT	INDUSTRY AND ACADEMIC			OTHER AMC LABS			OTHER GOVERNMENT AGENCIES			ESTIMATED COST TO ADMINISTER*	
	CONTRACT	TOTAL**	RATIO	CONTRACT	TOTAL**	RATIO	CONTRACT	TOTAL**	RATIO		
RDTE FUNDS	$K	$K	%	$K	$K	%	$K	$K	%	$K	%
6.1 RESEARCH	1,136	4,800	23.7	0	4,800	0	15	4,800	0.3	0	0
6.2 EXPLORATORY DEVELOPMENT	8,423	16,662	50.6	814	16,662	4.9	118	16,662	0.7	2,623	11.6
6.3 ADVANCED TECHNOLOGY											
6.3a	13,489	15,697	85.9	0	15,697	0	21	15,697	0	630	4.0
6.3b	4,000	6,025	66.3	0	6,025	0	0	6,025	0	0	0
6.4 ENG DEV	0	0	0	0	0	0	0	0	0	0	0
6.5 MGT & SUPPORT	113	590	19.2	2	590	0.3	0	590	0	0	0
6.7 OPER SYSTEMS	0	0	0	0	0	0	0	0	0	0	0
RDTE TOTAL	27,101	43,774	62.0	816	43,774	1.9	154	43,774	0.4	[illegible]	[illegible]
PROCUREMENT FUNDS AMC NON-AMC (OTHER ARMY) NON-ARMY PEMA TOTAL OMA FUNDS AMC NON-AMC (OTHER ARMY) NON-ARMY OMA TOTAL	THERE ARE NO ENTRIES IN ANY OF THE COLUMNS FOR PEMA OR OMA FUNDS										
[illegible]	27,101	[illegible]	[illegible]	816	43,774	1.9	[illegible]	[illegible]	[illegible]	[illegible]	7.4

*TOTAL EXPENDITURE FOR EACH LINE; i.e., 6.1, 6.2, ETC.

**IN-HOUSE COST FOR PURELY ADMINISTRATIVE DUTIES, BOTH TECHNICAL AND MANAGERIAL.

It is the policy of the Laboratory to utilize the expertise and specialized capabilities of other AMC Labs/Installations to conserve resources and prevent duplication of effort in accomplishing the Laboratory mission. During FY 75, a total of $2.7 million or 7.3% of this Laboratory's direct program funds were distributed to the AMC Labs/Installations shown in Table II. It is the intent of the Laboratory's management that the above policy will continue in the future.

TABLE II. AMC LABS/INSTALLATIONS USED BY AMRDL

AMC LABS/INSTALLATIONS	PURPOSE
NATICK LABORATORY	AERIAL DELIVERY & CARGO HANDLING
ROCK ISLAND ARSENAL	AIRCRAFT WEAPONS TECH–GUN & MOUNT
FRANKFORD ARSENAL	AIRCRAFT WEAPONS TECH –FIRE CONTROL
PICATINNY ARSENAL	AIRCRAFT WEAPONS TECH–FREE FLIGHT ROCKET TECHNOLOGY
WATERVLIET ARSENAL	RESEARCH ON STRUCTURES
BALLISTICS RESEARCH CENTER	RESEARCH IN SAFETY & SURVIVABILITY
ARMY MATERIAL & MACHANICS RSRCH CTR	RESEARCH IN SAFETY & SURVIVABILITY

ACCOMPLISHMENTS

PROGRAM BALANCE

The program structure for the Laboratory in FY 75 by funding allocations is reflected in Table III. The total Laboratory funding for the Army Aviation R&D Program, including reimbursable orders amounts to $43.8 million–a small percentage of the Army's total RDT&E budget, and even smaller in comparison with the total resources expended for airmobile systems development and procurement.

Joint participation agreements have enabled the Army and NASA to enter into mutually beneficial research and development programs which neither one could afford to pursue alone. Notable among such projects are the developments of the Tilt-Rotor Research Aircraft at Ames Research Center and the Rotor Systems Research Aircraft at Langley Research Center. These programs, along with others, have both military and civil applications and thus, improve the effectiveness of resource utilization on a national basis.

The Laboratory's Funding Summary; Command Schedule, Direct Funding Authority, and Obligational Authority, for the period of FY 72 through FY 75 is presented in figure 9. With careful planning and management, the Laboratory has obligated no less than 98.5% of its available program funds for each of these fiscal years. The 99.9% obligation rate for FY 75 exceeds the AMC goal of 96%. Continued success in this area depends on careful program

TABLE III. FY 75 FUNDING FROM ALL SOURCES INCLUDING CUSTOMERS (AS OF 30 JUNE 1975)

PROGRAM BREAKOUT

		SUBTOTAL	TOTAL
RDTE FUNDS			
6.1 RESEARCH		4,800	
6.2 EXPLORATORY DEVELOPMENT		15,903	
6.3 ADVANCED DEVELOPMENT		21,722	
6.3a	15,697		
6.3b	6,025		
6.4 ENGINEERING DEVELOPMENT		0	
6.5 MANAGEMENT & SUPPORT		590	
6.7 OPERATIONAL SYSTEMS		0	
RDTE TOTAL			43,015
PROCUREMENT FUNDS (PEMA)			
AMC – HQS		0	
OTHER		462	
NON-AMC (OTHER ARMY)		0	
NON-ARMY		0	
PEMA TOTAL			462
OMA FUNDS			
AMC – HQS		0	
OTHER		277	
NON-AMC (OTHER ARMY)		1	
NON-ARMY		20	
OMA TOTAL			298
GRAND TOTAL			43,774

INCOME BREAKOUT

	$
AMC SOURCE	
HQ, AMC	36,905
AVSCOM	6,820
OTHER AMC CUSTOMER	0
SUBTOTAL	43,725
NON-AMC CUSTOMERS (OTHER ARMY)	
ARMY TRAINING AND DOCTRINE COMMAND	1
SUBTOTAL	1
NON-ARMY	
NAVY	23
MARINE CORPS	25
SUBTOTAL	48
GRAND TOTAL	43,774

MODE OF FUNDING-APPROPRIATION
FUNDS IN THOUSANDS OF DOLLARS

management. Moreover, any significant amount of deferred or late release of funding could lead to serious obligation problems. Actions associated with late releases of funds could result in inability to explicitly define the work to be done and proposal evaluation lacking in proper depth and, hence, could adversely affect the quality of the ultimate R&D product.

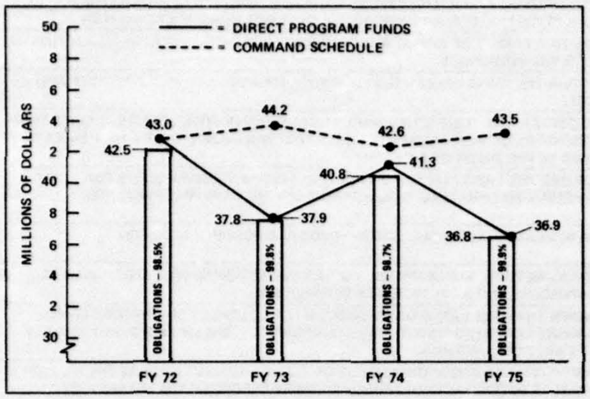


Figure 9. Funding history – FY 72-75.

The concept of single program element funding (SPEF) has gained significant acceptance since its implementation. The advantage of the SPEF program in providing broad local management flexibility by removing some intraprogram element reprogramming restrictions results in a decrease in some individual project visibility at higher levels. As a result, additional reports have been levied upon the Laboratory. It is believed that in order to obtain the optimum benefits from SPEF, additional reporting must be eliminated or reduced and minimum required information should be generated within the existing budget, accounting and program reports.

TECHNICAL ACHIEVEMENTS

The principal AMRDL R&D goal is to maximize mission capabilities and operational effectiveness of Army airmobile systems and minimize life-cycle costs. The FY 75 program for the Laboratory was responsive specifically to AMC's identified Goals and Major Thrusts (see figure 4) as they impact air mobility research and development. Table IV identifies some of the Laboratory's accomplishments in FY 75 that are directly related to these Major Thrusts.

The technological improvement objectives of the FY 75 projects were consistent with the near-term objectives identified in the Army Aviation RDT&E Plan of June 1974.

The charts presented in Appendix B show, for each of the Laboratory's six main technological disciplines, the Aircraft Systems Synthesis Project and Advanced Technology Demonstration, the program relationship and near-term technical objectives relating to AMC Goals and Major Thrusts. Because of the complex interactions and interdependencies of advancements in these areas, the achievements of many of the technical objectives depend on developments in more than one area. The proportionate share of project effort and allocated funds to each technology is indicated on the charts.

The following summary of some of the Laboratory's more significant achievements during FY 75 is divided into; Research (6.1), Exploratory Development (6.2), Advanced Development (6.3a), and Laboratory Support Actions (6.3b).

The published output of the Laboratory in terms of in-house and contract activity is documented in Appendix C.

AIR MOBILITY-PROGRAM CATEGORY 6.1

RESEARCH IN AIRCRAFT AERODYNAMICS

A detailed understanding of the aerodynamics of helicopters is particulary difficult to achieve due to the complex time-varying flow field in which a helicopter rotor operates. Helicopter performance, aeroelastic stability, vibration, static and dynamic loads, handling qualities, agility and acoustic signature are all directly related to the nature of the helicopter aerodynamic flow field. The aerodynamics discipline is divided into four subdisciplines as described in Table V. Advances in these fundamental areas of research can have a far-ranging impact in the exploitation and economics of the helicopter, and thus a wide range of the Laboratory's research effort is dedicated towards aerodynamics. The following technical discussion addresses FY 75 accomplishments in the four aerodynamic subdisciplines.

2-D Airfoil Sections – The major efforts in airfoil section develoment have traditionally been oriented toward fixed-wing aircraft applications. The unique flow field of the helicopter rotor requires a different set of airfoil characteristics than those desirable for fixed-wing aircraft. Significant progress has been made toward development of a technology for improving airfoil section aerodynamic characteristics for helicopter applications. A systematic approach to developing advanced airfoils which meet the peculiar needs of the helicopter has been undertaken and several advanced sections have been analytically defined. A systematic set of two-dimensional airfoil lift, drag and moment coefficient data for five different airfoil sections has been collected and correlated. Tests were conducted in the new Langley 6x18 Inch Transonic Wind Tunnel. The airfoils tested included a baseline NACA 0012 section, a Bell Helicopter Company (BHC) 540 section, and three advanced airfoil sections. These data were used in support of a program to develop an advanced rotor blade for the AH-1Q helicopter.

Oscillating Airfoils – The large oscillating airfoil experiment in the Ames 7x10 Foot Wind Tunnel, figure 10, has shown that a commonly accepted major hypothesis for the onset of dynamic stall is false, at least for the airfoils most commonly used for helicopter rotor blades. The relationship of the leading-edge bubble to the dynamic stall phenomenon is significantly different than that believed up to this time. A corollary is that dynamic stall characteristics are very difficult to modify if the changes to the airfoil are guided by the false hypothesis. However, if the true nature of flow separation is correctly taken into account, some modifications and improvements appear to be possible. The test results from the large oscillating airfoil experiments were used to evaluate prediction methods used by industry, and the importance of nondimensional time constants in defining moment stall and lift stall was demonstrated.

Transonic Flow Effects on Rotors – The outboard end of a rotor blade may be subjected to transonic flow effects, especially in high speed forward flight. An understanding of the combination of the unsteady nature of the rotor flow field in regions of transonic speeds is needed. In a program designed to advance this understanding, unsteady effects in two- and three-dimensional transonic flows on helicopter rotor blade tips have been calculated for the first time, although the configurations studied were limited to circular arc, nonlifting airfoils. Figure 11 shows the good correlation of analysis and experiment for a non-rotating wing.

TABLE IV. REPRESENTATIVE FY 75 ACCOMPLISHMENTS IDENTIFIED TO MAJOR THRUSTS

FY 75 ACCOMPLISHMENT	MAJOR THRUST	PROJECTED BENEFITS AND IMPACTS
ROTOR FLOW FIELDS	INCREASE AIRCRAFT PERFORMANCE	LASER VELOCIMETER AND LASER/DOPPLER TECHNIQUES LEADING TO THE MEASUREMENT OF ROTOR DOWNWASH AND BOUNDARY OR CIRCULATION PROVIDE MORE ACCURATE PREDICTION OF ROTOR IMPROVING ROTOR LIFE AND VIBRATION CHARACTERISTICS.
AIRFOIL IMPROVEMENT	INCREASE AIRCRAFT PERFORMANCE	GAIN IN BASIC KNOWLEDGE OF FLOW SEPARATION PHENOMENA OF HELICOPTER AIRFOILS IN STALL WILL LEAD DIRECTLY TO IMPROVED MANEUVERABILITY OF HELICOPTERS UNDER ALTITUDE, HIGH TEMPERATURE CONDITIONS, WHILE RETAINING A POTENTIAL FOR AN INCREASE OF 5% IN ROTOR HOVER EFFICIENCY.
CARGO HANDLING	INCREASE AIRCRAFT PERFORMANCE	THE APPLICATION OF KEVLAR 29 TO A FAMILY OF CARGO SLINGS HAS THE POTENTIAL OF A 50% REDUCTION IN SYSTEM WEIGHT OVER PRESENT SLING ASSEMBLIES.
COMPOSITE TAIL CONE	INCREASE AIRCRAFT PERFORMANCE	THE ALL COMPOSITE TAIL CONE FOR THE AH-1G OFFERS THE POTENTIAL OF A 20% SAVINGS IN WEIGHT AND A 20% SAVINGS IN LIFE CYCLE COST.
CRASHWORTHINESS PREDICTION	SAFETY & SURVIVABILITY	CRASH TESTING OF A CH-47 HELICOPTER HAS VERIFIED AN ANALYTICAL CRASH MODEL (KRASH). USE OF THIS MODEL WILL ENABLE ENGINEERS TO DESIGN AIRFRAMES WITH GREATER CONFIDENCE THAT A HIGHER RATE OF SURVIVABILITY CAN BE ACHIEVED IN THE EVENT OF A CRASH.
HELICOPTER ICING	IMPROVE SAFETY & INCREASE PERFORMANCE	RESEARCH CONDUCTED HAS FORMED THE BASIS FOR THE DESIGN AND TESTING REQUIREMENTS FOR ARMY HELICOPTER ICE PROTECTION SYSTEMS TO ENSURE MAXIMUM EFFICIENCY WITH MINIMAL PENALTIES AND LIFE CYCLE COSTS.
UH-1 ALASKA FLIGHT TEST	AIRCRAFT SAFETY	LOW TEMPERATURE OPERATION REVEALED INCREASED ROTOR LOADS AND POSSIBLY REDUCED FATIGUE LIFE.
INSPECTION SCHEDULE IMPROVEMENT	EFFECT COST REDUCTION	USE OF AN ADVANCED ANALYTICAL METHOD TO MODIFY HELICOPTER INSPECTION SCHEDULES SHOULD PROVIDE FOR A REDUCTION OF 25% IN MAN-HOURS AND A 10% INCREASE IN READINESS.
COMPRESSOR MODELING	EFFECT COST REDUCTION	EXPERIMENTAL TESTS HAVE SHOWN THAT THE LARGE DATA BANK ON LARGE SCALE COMPRESSORS CAN BE USED TO DESIGN SMALL GAS TURBINE COMPRESSORS WITH HIGH CONFIDENCE. THIS SHOULD SIGNIFICANTLY REDUCE ENGINE DEVELOPMENT TIME, COST, AND RISK.
ARMS MODEL	DECREASE LIFE CYCLE COSTS	THE ARMS CAN SIMULATE THE OPERATIONAL AND MAINTENANCE OF FLEET AIRCRAFT SUCH AS THE UH-1, CH-47, AND AH-1. THE MODEL OFFERS GREAT POTENTIAL IN DETERMINING MORE PRECISELY THE SPARES AND PROVISIONING FOR NEW AIRCRAFT ENTERING SERVICE.
SUPERHARD TRANSPARENT COATINGS	REDUCE LIFE CYCLE COSTS	SUPERHARD TRANSPARENT COATINGS FOR HELICOPTER CANOPIES, WITH HARDNESS GREATER THAN GLASS CAN REDUCE CANOPY SCRAPPAGE BY UP TO 50%.

TABLE V. AERODYNAMICS SUBDISCIPLINES WITH FIELD OF ENDEAVOR

SUBDISCIPLINE	FIELD OF ENDEAVOR
FLUID MECHANICS	TO OBTAIN BASIC UNDERSTANDING OF THE ROTOR FLOW FIELD AND THE MECHANISMS INVOLVED IN THE GENERATION OF STATIC AND DYNAMIC LOADS ON ROTORS AND OTHER HELICOPTER COMPONENTS.
DYNAMICS	TO ESTABLISH AEROLASTIC STABILITY OF ROTOR BLADES AND THE COUPLED RESPONSE AND STABILITY OF THE ENTIRE HELICOPTER.
CONTROL & HANDLING QUALITIES	TO ESTABLISH AERODYNAMIC LOADS ON THE ROTOR AND AIRFRAME PROVIDING STATIC AND DYNAMIC RESPONSE CHARACTERISTICS WHICH ARE COMPATIBLE WITH PILOT CAPABILITIES AND MISSION REQUIREMENTS.
ACOUSTICS	TO REDUCE THE AERODYNAMIC AND MECHANICAL NOISE GENERATED BY THE HELICOPTER.

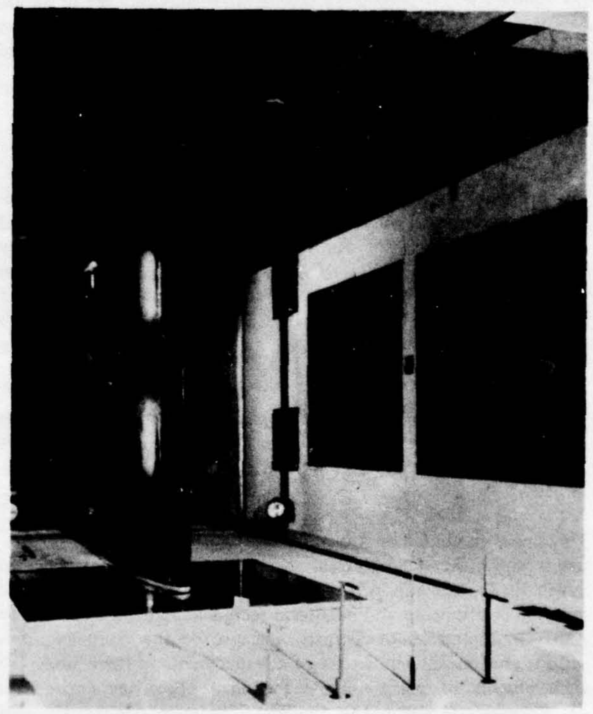


Figure 10. Oscillating airfoil in 7 x 10 foot wind tunnel.

Some guidelines for the relative importance of three-dimensional and unsteady effects for both blade design and blade airloads calculation have been developed.

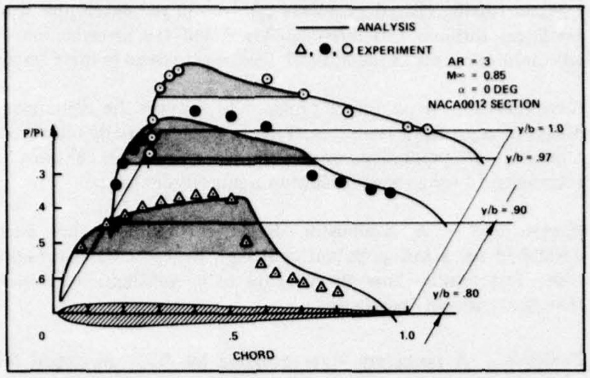


Figure 11. Transonic pressure distributions near tip of a constant chord semi-span wing.

Rotor Flow-Field Test Techniques – Rotor downwash, trailing tip vortex and bound circulation on the blade of a teetering rotor model have been measured in the Ames 7x10 Foot Wind Tunnel with a laser velocimeter, figure 12. Color Schlieren techniques have been developed and demonstrated. Laser/doppler radar has been used to make wake measurements behind the oscillating yaw rig in the Langley 7x10 Foot Wind Tunnel. Oscillating airfoil equipment has been designed and fabricated for the Langley Transonic Wind Tunnel. A program has been initiated to provide measurement of local rotor blade angle of attack in flight and various sensors have been studied for applicability. Advanced laser velocimeter methods which will allow three dimensional measurements in the rotor flow field are being investigated.

Figure 12. Laser velocimeter.

Aeroelastic Stability Analysis – Dynamic stability of rotors in general, and hingeless rotors in particular, is an area where a more detailed understanding of basic phenomena is required. A number of analysis efforts have been proceeding in this area. Previous stability analyses of uniform elastic rotor blades in hover mounted on a fixed hub have been extended to include the effects of droop, sweep, torque offset, and root pitching. Analysis of flap-lag stability in forward flight for the fixed hub condition using rigid blades and a root spring to model the rotor has been accomplished. An offshoot of this analytical effort was the derivation of an approximate closed form solution for the lead-lag damping in hover. Nonlinear equations of motion for the elastic bending and torsion of twisted nonuniform rotor blades and flapping response characteristics of hingeless rotor blades by a genralized harmonic balance method have also been developed. The effects of pitch-lag, flap-lag and pitch-flap coupling on blade stability in hover were examined using the rigid blade equations. The study showed that there are beneficial combinations of couplings that can significantly augment the damping of the blade lead-lag motions in hover at zero blade pitch.

Rotor Dynamics Model – The 5.5 ft-diameter Rotor Dynamics Model (RDM) shown in figure 13 is being developed as a major tool for obtaining experimental data to correlate with theoretical analysis of basic dynamic phenomena. Phase 2 and Phase 3 experiments with the rotor dynamics model have been completed. The objectives of the Phase 2 test were to examine the suitability of the model for stability testing, and to develop various testing techniques for determining the damping of the lead-lag motions. It was determined that the present hub design is not adequate for stability testing. As a result, a new hub will be designed for the model. The objective of the Phase 3 experiments was to investigate static loads in hover. Preliminary data was obtained for a joint research program with the French ONERA. Analysis of the data is being held in abeyance until the program course is decided. A set of flexures have been designed and built for the RDM to check out the effect of combined couplings on damping of lead-lag motions for a soft inplane rotor. These flexures will be used to verify a design concept for which AMRDL personnel have submitted a patent application and prepared a NASA Technical Brief.

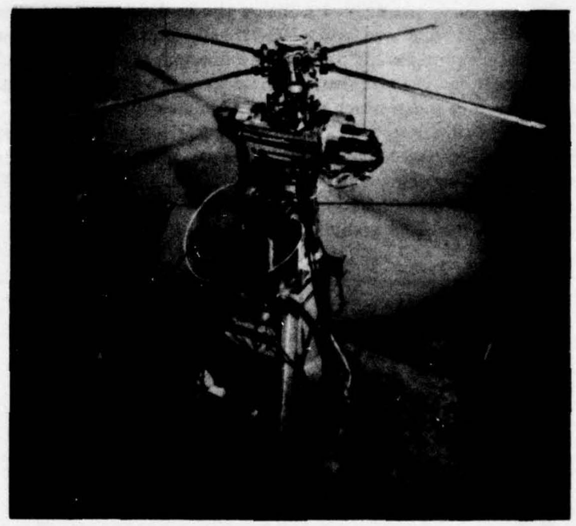


Figure 13. Rotor Dynamics Model.

In-Flight Far Field Noise Measurement Concept A new technique for measurement of helicopter far field impulsive noise data in flight has been developed. It provides for the first time a means of measuring the external impulsive noise of a helicopter in flight without ground reflection and doppler effects. The technique, uses a fixed-wing aircraft as a microphone platform which flies in a fixed position ahead the helicopter. Figure 14 shows how the data system in the airplane is synchronized with the rotation of the helicopter rotor so that the rotor azimuth position with respect to the measured data can be determined. Successful test flights using this technique on a UH-1H have been made and further development of the technique is planned.

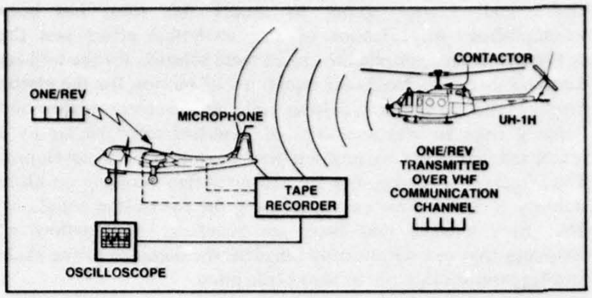


Figure 14. In-flight far field noise measurement concept.

Wind Tunnel Acoustic Measurements. – An attempt to acoustically treat the walls of the 7 x 10 foot wind tunnel to allow measurement of impulsive noise characteristics of model helicopter rotors has been successful. Data taken from microphones mounted in the tunnel during tests of a scale model UH-1H rotor showed that lining of the tunnel walls with "scotch-felt" material resulted in reduction of reflected noise to a level where good acoustic measurement of impulsive noise could be made. The impulsive noise measurements taken at locations corresponding to those at which in-flight data is available show excellent agreement between flight and tunnel results. Noise measurement data taken at various microphone locations will be used to triangulate the origin of blade slap under a range of descent conditions. Color enhanced Schlieren and smoke pictures have also been made to aid in the interpretation of the acoustic events.

Impulsive Noise – The character of high speed helicopter impulse noise has been investigated utilizing the in-flight far field noise measurement technique with a UH-1H helicopter. Figure 15 shows a plot of measured sound pressure as a function of time for a blade slap condition. The strongest acoustic wave is a negative (rarefaction) pressure pulse which dominates the acoustic signature. The fact that it is a negative pressure pulse has not previously been recognized by the helicopter community, although it was first observed during some early propeller acoustic measurements. This is a significant determination that will have considerable influence on future acoustic programs.

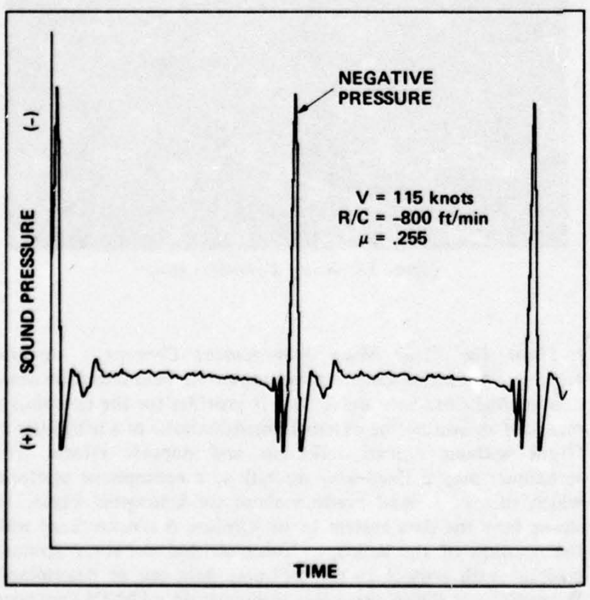


Figure 15. Impulsive noise time history.

RESEARCH IN PROPULSION

Research in propulsion consists of basic research, conducted by the Lewis Directorate jointly with NASA, aimed at advancing the technology of propulsion and drive trains. The work is directed towards solving special problems involved in the development of *small* gas turbines (20 lb/sec airflow), and the investigation of advanced concepts in mechanical devices employed in drive trains.

Compressors – A computer program to support the preliminary design of centrifugal compressors has been substantially improved. More accurate predictions of performance parameters can now be accomplished for a broader range of input requirements.

Combustors – A combustor design methodology has been developed for a low pollutant emitting swirl-can combustor concept. Test results show the concept to be substantially cleaner than conventional combustors.

Turbines – A boundary layer program has been developed for predicting the heat transfer to the walls of a turbine blade cooled by discrete hole film cooling. The method has been applied to some experimental data and shows good agreement.

Analysis and analytical modeling of the heat transfer processes in the passages of liquid cooled gas turbines has been initiated.

A thermal analysis, completed for metallic turbine blades, has been extended to include ceramics (SiC and Si_3N_4). The generated heat transfer information will be used in a stress analysis of the ceramic version of the vane.

Material – Several NiCrAl alloys with protective coatings have been ranked with respect to life expectancy using a newly developed fatigue parameter. These results for a 5 mil thick coating give needed information to the designer for the selection of propulsion technology materials.

Polymers have been studied as candidates for centrifugal compressor rotors. Chemical processing has been evaluated to improve the creep resistance at 600°F which is a problem. The specific strength of polymers has been demonstrated to be 80 percent greater than metals which, if totally utilized, represents a sizable weight reduction in gas turbine engines.

RESEARCH IN STRUCTURES

Research in the aircraft structures technology base is, primarily, committed to developing new ways of safely and economically transmitting loads throughout an aircraft with minimum weight penalty. This effort is largely one conducted by the Langley Directorate with the following significant accomplishments for FY 75.

Computational Techniques – Methods for quantifying and utilizing a structural damping parameter in helicopter dynamic system analysis can permit more accurate determination of structural loads, vibrations, and stability boundaries. In order to achieve this improved capability a mathematical model has been developed for the structural damping of composites. Some conformity has been established with experimental data. Experimental data obtained thus far for boron-aluminum and boron-epoxy composities suggests that a tri-parameter anelastic mathematical model can be used to simulate experimental results. Working with this model, it has been possible to simulate the uni-axial boron-aluminum test results.

The effects of viscoelastic, air and magnetic damping and coriolis forces on the stability of stationary and rotating deformable bars subjected to non-conservative mechanical loads have been mathematically described.

Composite Materials – The mechanisms of fatigue damage in fibrous composites have been determined using a combination of scanning electron microscopy, fractography, and progressive selective etching techniques. The extent and nature of the fatigue damage varies through the thickness. In the surface layers, the extent of fatigue crack growth, or sometimes delamination, is the same for the fibers and matrix. In the subsurface layers, the crack in the matrix leads the surface crack by several times the specimen thickness. However, fracture of the fibers lags the surface crack. It has been found that the residual strength of a specimen containing such fatigue damage may be equal to or greater than the strength of a specimen that is not fatigue cycled.

Composite Applications – A process has been developed for fabricating integral sheet-stringer-frame structures from composite materials. The components are used in an intermediate shear web design for the CH-53 in which the webs are permitted to buckle below limit load in transmitting shear. The composites are a hybrid of graphite (70%) for high strength and stiffness, and kevlar 49 (30%) for toughness and durability. The panel design (figure 16) as applied to CH-53 aircraft offers 18% weight reduction and 20% unit cost reduction.

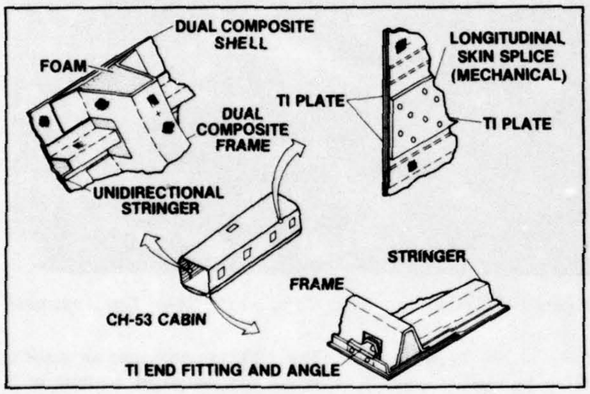


Figure 16. Hybrid composite design concept for CH-53 fuselage.

A pre-stressed rotor blade spar concept has been developed and its feasibility verified by simulated blade fabrication and testing. The simulated blade made in the form of an oval stainless steel tube was wrapped with fiber glass and cured (figure 17). The tube was cryogenically cooled and stretchformed. It was confirmed that the residual compressive stresses in the steel tube improved the fatigue life of the part and increased its damage tolerance.

Fatigue/Fracture Control – Experimental results of fatigue crack propagation rate and fracture toughness measurements in 1-inch compact specimens of laminated steel and laminated aluminum composites have been reported for three orientations of cracks – crack arrest configuration with the crack normal to the laminae; crack normal to edge of the laminae; crack growing in the plane of one of the laminae – with the crack arrest configuration possessing the greatest fatigue life.

An expression for energy release rate in an arbitrary direction for a crack subjected to complex loading conditions has been developed. Direction of crack extension is obtained from the maximum value of this expression.

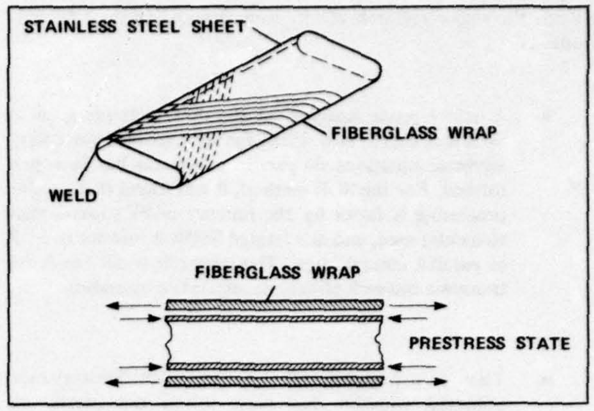


Figure 17. Pre-stressed rotor blade spar concept.

RESEARCH IN MATHEMATICS

The basic mathematical research efforts of AMRDL are directed, primarily, to the general domain of aerodynamics, propulsion, structures, and decision analysis. The end results of these efforts contribute to fill the technological needs and requirements of advanced airmobile systems. Mathematics and computers are daily tools to research and development efforts. The Laboratory program on mathmatical sciences and computing includes research in mathematics, CAD-E, parallel computation, decision risk analysis, and prelimiminary design computational methods. The major emphasis of the Laboratory are presented below.

Mathematics – Mathematical research has been applied to the problem of rotor blade bending, which, for years, has resisted efforts to obtain closed-form solutions. An in-house effort was successful in solving the equation analytically. New mathematical functions, named rotor functions, and their unique properties have been obtained. On the basis of these functions, the analytical solution to the complete static equation characterizing the static behavior of a rotating helicopter blade with constant stiffness and uniform mass distribution has been obtained. It was found that, among other things, the closed form solution possesses the following intrinsic properties:

- For the articulated rotor, two loadings are different by a multiplicative constant if and only if their corresponding solutions (static behavior) are different by a multiple of the same multiplicative constant.

- For the hingeless rotor, such a relationship between the solution and the loading does not exist unless the blade coning angle is zero.

A unique system that includes two one-of-a-kind devices, the ILLIAC IV Processor and the Unicon Laser Memory – an integrated system of data processing, information storage, and communications equipment – is located at NASA-Ames Research Center. Through the Army/NASA agreement, the capability of the ILLIAC IV is available to AMRDL. The ILLIAC IV processor is the major data processing resource in the system (figure 18), and is dedicated to the execution of user programs in vector (parallel) mode. This fourth generation computer, with its battery of 64 slave computers, can execute between 100 million and 200 million instructions per second. Each of its 64 processing elements is a powerful computing unit in its own right. The ILLIAC IV system has a mass storage capacity of a billion bits on each of its 128 tracks, totaling a trillion bits. Such capability can provide a major improvement for the solution of problems in aircraft design. In

FY 75, the major research efforts were devoted to the following studies:

- A convergence analysis of iterative methods such as SOR and accelerated SSOR for solving linear systems of algebraic equations via parallel processing has been performed. For the SOR method, it was found that parallel processing is faster by the number of PE's (processing elements) used, and accelerated SSOR is inferior to SOR in parallel computation. This research result facilitates transonic research efforts via parallel computation.

- The two-dimensional, transonic, small-disturbance, potential equation has been solved numerically via parallel computation.

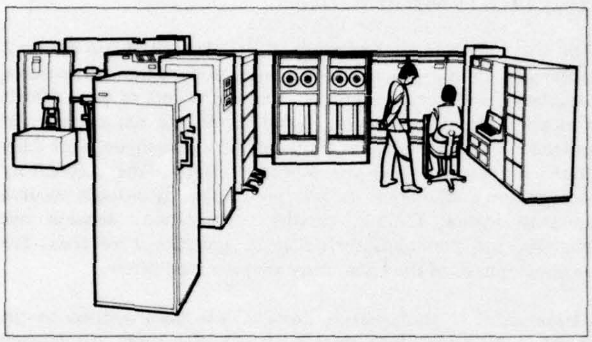


Figure 18. Institute of Advanced Computation (IAC) System (including ILLIAC IV Large Scale Parallel Processor).

Operations Research – Decision risk analysis is a subject which has been under continual development and refinement and has been applied to various systems or programs. The significant accomplishment is the development of two algorithms: cost impact and schedule variance. These algorithms are technically based in that the data to exercise the algorithms are collected from a technical risk assessment. The methodology not only allows the proper integration of technical aspects to the cost and schedule, but also presents outputs accommodating "what if" type of questions. In particular, potential cost growth and schedule slippage considerations are exhibited which provide a balanced appraisal for decision making. For presentation and publication, a paper entitled "A Risk Approach to Source Selection" has been accepted for presentation at the 4th Annual DOD Procurement Research Symposium. Also, a quantitative approach to procurement risks has been done and the research result has been accepted for presentation in the Joint National Meeting of ORSA and TIMS, 1975. Furthermore, in addition to the previous studies conducted for systems such as Tilt-Rotor Research Aircraft, Heavy Lift Helicopter, and Improved Cobra Armament Program, the result of this research effort has been applied to the Remotely Piloted Vehicle.

The AMC Scientific and Engineering Computer Network (SENET) has begun operations with the central objective of sharing its large-scale computers in support of scientific and engineering applications among the Army laboratories throughout the U.S. AMRDL staff contributed to the analysis of the various so-called retail computing issues associated with this novel network concept, and research will be continued in the development of game strategies for subscription.

AERONAUTICAL TECHNOLOGY – PROGRAM CATEGORY 6.2

AERODYNAMICS TECHNOLOGY

The Laboratory effort in exploratory development of aerodynamics technology is conducted by the Ames, Eustis and Langley Directorates. A technical discussion of the major FY 75 accomplishments follows.

Rotor Test Apparatus – Under a joint Army/NASA program, the design, development, and fabrication of a universal helicopter rotor test apparatus (RTA) for use in the Ames 40x80 Foot Wind Tunnel has been completed. The test module permits evaluation of the dynamic, aeroelastic, and performance characteristics of full-scale rotors under full-scale flow conditions without the risks attendant to trying new concepts initially in flight. Initial checkout of the apparatus showed that the wind tunnel support system would require additional damping in order to avoid potential system instabilities while testing large rotors. As a result, modifications to the wind tunnel support system have been made. Figure 19 shows the Controllable Twist Rotor (CTR) mounted on the RTA in test in the 40x80 foot wind tunnel.

Figure 19. Controllable Twist Rotor on the Rotor Test Apparatus.

Controllable Twist Rotor – The CTR concept uses an aerodynamic control surface located on the outboard section of a torsionally-soft rotor blade to vary the twist of the blade collectively and cyclicly. In order to determine the effectiveness of such a system in reducing loads and vibration, a full scale rotor with both conventional and twist control system has been built and whirl tested. Whirl tower results demonstrated satisfactory mechanical, structural and dynamical characteristics and that the aeroelastic response of the rotor in terms of both frequency and amplitude are in agreement with analytical predictions. Wind tunnel tests (see figure 19) are currently under way to identify the actual potential of the concept on full-scale hardware in forward flight.

Drag Prediction – Up to 50% of the drag of current helicopter designs is attributed to the rotor hub and pylon. Wind tunnel data on rotor pylon/hub configurations and components have been systematically collected and a technique developed for prediction of hub drag. A low drag hub configuration has been defined. Also, two areas of fuselage drag are being investigated analytically; three dimensional flow separation areas, and the effect of the presence of the rotor on the flow around the fuselage.

Modeling – The Laboratory has continued the updating and enhancement of an in-depth aero mechanics computer model in an effort to respond to both Army and Industry needs for a unified tool which can be used effectively for the calculation of rotary

wing aircraft performance, loads, stability and control, dynamics, and maneuver characteristics. The model is continually updated to enhance its utility. Considerable effort is being expended to make the model applicable to a full range of rotor types and control concepts through correlation with a variety of different types of helicopters. As a parallel effort, the long-range simulation needs of the helicopter development community are being assessed in order to guide comprehensive helicopter modeling efforts in the most cost-effective manner.

Handling Qualities – A better understanding of rotary wing aircraft handling qualities, characteristics and requirement is required to develop techniques for identification of parameters having significant efforts on handling qualities. Such an understanding is required for correlation of existing aircraft characteristics and analysis in order to apply meaningful handling qualities criteria and develop accurate and meaningful analytical prediction techniques for the design and evaluation of new aircraft. A technique for processing flight test data to a form which can be used in analytical expressions have been developed. This "stability derivative extraction" process has been used in conjunction with newly developed flight test techniques to obtain stability derivatives for CH-54 and UH-1 helicopters. An attempt to correlate these derivatives with a 6-degree-of-freedom analysis of the helicopter did not produce the desired level of agreement. It was concluded that in addition to rigid body response additional degrees of freedom describing rotor response are required to provide a realistic analytical representation of helicopter handling qualities. A 9-degree-of-freedom representation will be investigated. In an independent effort, vehicle description and handling qualities data has been collected from various manufactureres on the OH-6A, BO-105, L-286, CH-53D, AH-1G, and UH-1H helicopters. These data will be systematically examined for significant parameter identification to provide correlation for the man-in-loop simulation program.

Man-In-Loop (MIL) Simulation – Development of MIL simulation capability for Low Level Night Operations (LLNO) with emphasis on low speed nap-of-the-earth (NOE) and terminal area operations is continuing. The basic limitation is simulator visual system capability. Among the most effective realistic visual systems available for MIL simulators are television pictures from a camera which traverses a scale model terrain board of normal ground conditions. NOE flight requires considerably more detail and a larger scale than is required for fixed-wing and STOL aircraft. Therefore, a 400:1 scale model of a segment of the Hunter Liggett Military Reservation, where much of the flight evaluation of LLNO flight is undertaken, has been made for use in NOE simulations. Figure 20 is a photograph of a test segment of terrain demonstrating the detail of the terrain board. A rear projection technique has been developed to provide visual capability to the rear of the simulated vehicle.

Generalized Rotor Aeroelastic Model – The Generalized Rotor Aeroelastic Model (GRAM) was tested in the Langley Transonic Dynamics Tunnel. The purpose of the test was primarily to verify the aeroelastic stability characteristics of a research rotor configuration under study by Bell Helicopter Company. The rotor is a four-bladed, soft-inplane hingeless rotor which was designed and fabricated by Bell under their IR&D program. Two other Bell IR&D rotors were also tested: a wide-chord teetering rotor with a flapping hinge at 0.50R and a wide-chord teetering rotor without the flapping hinge. The wind tunnel test program was a cooperative Langley/Bell effort in which Langley supplied the wind tunnel and the model on which to run the rotor, and Bell supplied the rotors. Figure 21 shows the wide chord model in the wind tunnel.

In-Flight Acoustic Measurement System – The in-flight acoustic measurement system (IFAMS) shown in figure 22 is a research tool designed to study rotor noise phenomena. IFAMS utilizes

Figure 20. Sample of terrain board modeling detail.

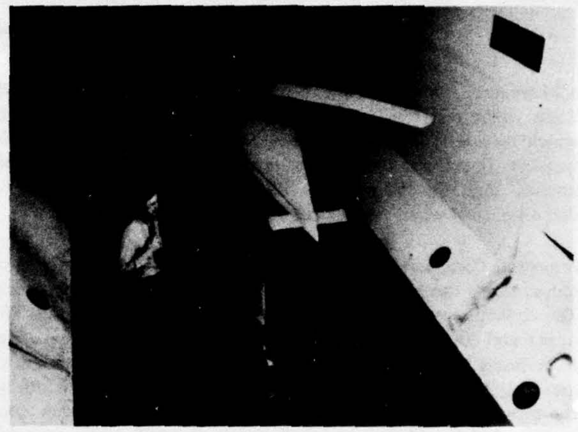


Figure 21. GRAM with BHC wide-chord rotor.

state-of-the-art technology and operates in close proximity to the acoustic source; measuring its spectral characteristics, and defining its propagation path. The present system uses two ½-inch microphones, one on each side of the helicopter to record advancing and retreating rotor blade acoustics, each extending 5 feet from either side of the aircraft. The results from this system are shown in figure 22 as applied to a two-bladed UH-1H helicopter. The data, on the left, show a pressure time history and spectrum from the advancing-side microphone, and data on the right are from the retreating-side. The flight conditions are 70 knots and a 600 ft/min rate-of-descent. The advancing side pressure time history shows amplitude spikes directly attributable to main rotor blade/vortex interaction at blade passage frequency. The retreating-side pressure time history shows no distinguishing pressure peaks and is about 20 dB below the spectra of the advancing-side. The predominant peaks of the retreating-side spectrum are due to noise created by the anti-torque tail rotor. This new measurement capability is also being further developed such that it can be applied to the location and definition other than those that are impulsive in character.

STRUCTURES TECHNOLOGY

Flight Tests in Alaska – Final AMRDL Technical Report 75-3 has been published which documents the findings of a single instrumented UH-1H helicopter that was test flown in Alaska. The main rotor blade and hub were instrumented with strain gages to measure the loads incurred by these components during extreme

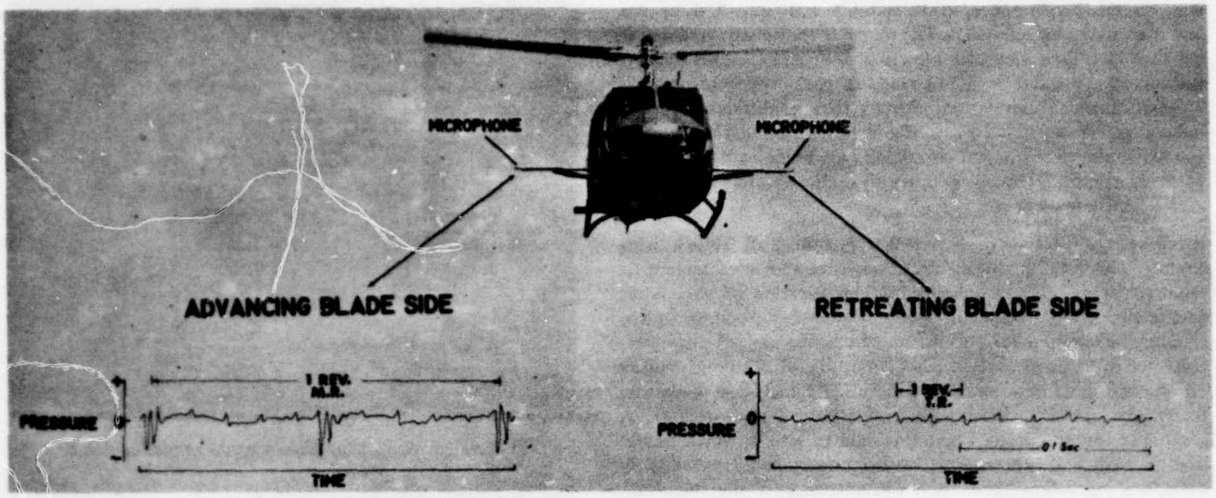


Figure 22. In-flight acoustic measurement system on UH-1H helicopter.

cold weather operations. These findings have been compared with Bell's flight test loads substantiation for the same components which reveals that the loads are substantially greater due to cold weather operations because of mach number influence. This implies that the fatigue life of critical components may be fore-shortened when used in extreme cold weather climates.

Improved Composite Rotor Hub – An improved composite rotor hub concept has been selected and preliminary design performed. The concept consists of upper, intermediate, and lower plates. The upper and lower plates are essentially flat except for local reinforcements and the intermediate plate is deeply dished. Hub material is graphite laminae covered by one ply of E-glass cloth on the top and bottom surfaces. Transition regions at the main rotor mast and rotor blade pin locations are reinforced by titanium laminae. R&M and failsafe characteristics have been analyzed. Radar cross section has been estimated based on empirical data.

Selection of Advanced Structural Design Concepts – Estimated weights and cost of selected advanced structural design concepts have been compared against baseline aircraft (conventional structure). Two comparison methods have been employed, the first being to determine the improvements in useful load and/or performance characteristics over the baseline aircraft at the equivaent gross weight, the second being to determine the weight, size and cost reductions that could be achieved when compared to the useful load and performance of the baseline aircraft. Analysis of the selected advanced structural/composite concepts indicates a 20 percent weight and cost reduction over the baseline configuration with inherent characteristics of improved repairability, maintainability and vulnerability.

Tail Rotor Aeroelastic Analysis – A study has been performed to develop the capability to use high speed digital computational procedures in the analysis of tail rotor aeroelastic stability (TRASTAN). This study included consideration of blade elastic properties, the pertubational aerodynamics and blade root retention in the rotating system. The mathematical analysis also included the coupled effects of anisotropic control system properties and the tail-pylon/tail-boom/fuselage inertial, aerodynamic and elastic properties in the fixed system. The initial utilization of the computer program was aimed at the UTTAS rotor. A review of the results indicates that the TRASTAN program represents a significant new mathematical procedure, useful for analyzing rotor stability.

PROPULSION TECHNOLOGY

Technological activities in propulsion, which includes drive trains, covers the development and testing of components of power devices and of drive trains. The 6.2 propulsion activities are conducted by the Eustis and Lewis Directorates. Technical discussions covering some propulsion 6.2 accomplishments, are presented below.

Inlet Protection Devices – The use of an inlet particle separator in an engine installation has resulted in substantial reductions in foreign object damage, and in greatly increased tolerance to engine operation in a sand and dust environment. A program has been completed which provides design criteria and a draft design guide for inlet particle separators for gas turbine engines. The results of this program have been employed in the T-700 engine development program with favorable effects on system performance.

Compressors – The design and calibration of a single-stage radial compressor with a 10:1 pressure ratio was completed, showing an efficiency at peak pressure ratio of 78.4 percent. Engine performance and fuel economy will be improved by the use of this concept.

Combustors and Emissions – Two combustor concepts which provide reduced levels of emissions have been demonstrated by engine testing which verified a 50 percent reduction in the original level of emissions. One low-emissions combustor has been incorporated into an updated T-63 engine to provide increased tolerance to water ingestion which had previously caused flameout. The new combustor has accepted a slug of 200 milliliters of water with no damage or flameout.

Turbines – A miniaturized probe (figure 23) for measuring turbine blade-to-shroud clearances during both steady-state and transient conditions has been demonstrated. These measurements will provide guidance for improving engine performance and fuel economy.

Drive Trains – A method has been devised for predicting the scoring-limited loading of spur, helical, and spiral level gears.

The capability of a "free-planet" gear set has been tested. This concept supplies a high reduction ratio without the use of planet pinion bearings. Test results showed good mechanical efficiency, good load distribution, and potential advantages in weight and cost.

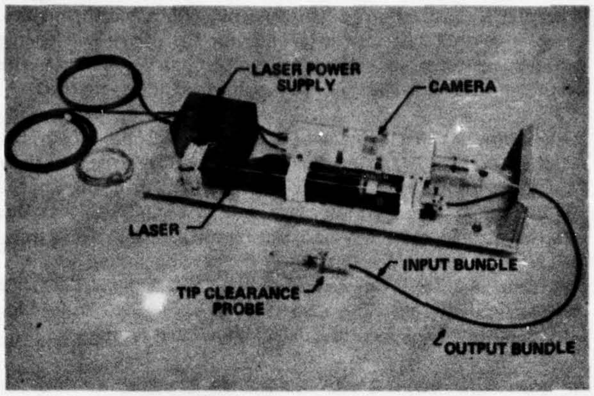


Figure 23. Miniaturized tip clearance probe.

Flight testing is being completed on a circumferential carbon oil seal for the UH-1 input quill shaft. The use of this new seal corrects an unsatisfactory condition in the present lip seal.

RELIABILITY AND MAINTAINABILITY

The basic R&D effort in this area is to conduct those exploratory development programs necessary to define the relationship between R&M quantitative characteristics and system, subsystem, and component design criteria/arrangements and test requirements. The 6.2 R&M effort is conducted by the Eustis and Lewis Directorates. FY 75 accomplishments in the R&M area are as follows.

Arms Model Development – The ARMS (Aircraft Reliability and Maintainability Simulation) model (figure 24) which simulates the operational and maintenance concepts of designed aircraft has been validated on several aircraft including the UH-1, CH-47, and AH-10. Further application and usage of the model will be reflected in evaluations of multiple mission and support concepts of new development aircraft such as the UTTAS, AAH, and RPV Wide interest in the ARMS model has been shown by other Government agencies and several aerospace companies.

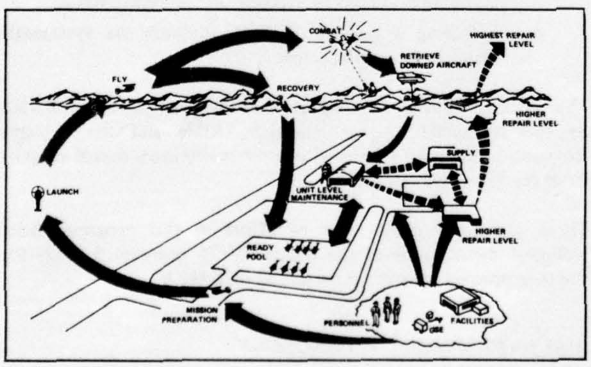


Figure 24. The ARMS Model.

Project Inspect – Efforts to find improved methods for reducing high maintenance work load associated with periodic inspections of aircraft has resulted in the derivation of inspection schemes that require less manpower and less aircraft downtime with no compromise in flight safety.

Phase I efforts of Project Inspect involved analytic derivation of inspection schemes principally related to the UH-1 and CH-47. Under Phase II of Project Inspect, six UH 1 companies at Fort Campbell, three acting as control companies and three using the new phased inspections, are undergoing test. It is anticipated that a reduction of 25% in manhours/flight hours and a 10% increase in readiness will be achieved.

Superhard Transparent Coatings – The investigation of superhard transparent coatings for helicopter canopies has demonstrated good results from coupon tests. Hardness greater than that of glass can be achieved through coating of stretched acrylic and polycarbonate panels. Plans call for testing of full size structures in the future. This type of coating will allow up to 50% reduction of canopy scrappage at depot overhaul.

Diagnostic Logic Algorithm Development – A maintenance logic model for use in evaluating the diagnostic allowables of designed hardware has been recently developed to allow design engineers to determine the type and number of test points needed for fault-isolating malfunctions in hardware. The algorithm is generic in that the designer defines the hardware physical and functional characteristics from which the computer constructs a logic model. From this, alternative test points and features can be quickly evaluated using conversational mode computer.

SAFETY AND SURVIVABILITY

Safety and survivability technological development effort is presently directed towards the development of techniques for defeating or degrading the effect of known or potential threat weapons and target acquisition devices through aircraft signature reduction and aircraft design, weapon effectiveness reduction, and crash survivability improvement. The development efforts are conducted by the Eustis Directorate. FY 75 accomplishments are presented below.

Flight Safety – A crash-damaged CH-47C helicopter, having been repaired by the contractor to the extent that major structures and components were representative of a flight-worthy aircraft, was instrumented for crash analysis and dropped from a height of 51.4 ft to simulate crash conditions, figures 25 and 26. By obtaining technical data on the dynamic behavior of large helicopter structures and components in the crash environment, design criteria can be developed which will improve the crashworthiness and mission capability of future Army aircraft. A final report on this test will be published.

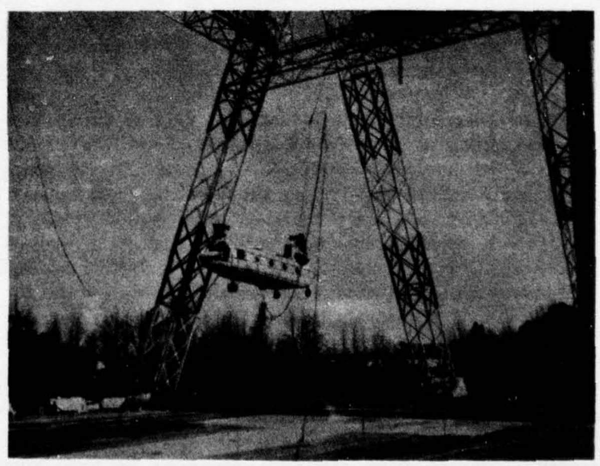


Figure 25. Dynamic crash test rig with CH-47C test helicopter.

Figure 26. CH-47C crash test.

Ballistics – Ballistic test programs were conducted both in-house and on contract to examine concepts to protect helicopter fuel tanks from 23mm HEI impacts. Indications are that proper overall fuel system design and judicious application of advanced materials can significantly reduce fuel tank vulnerability to this threat. Other ballistic tests were conducted to examine the vulnerability of helicopter components to threat weapons and to determine the most promising avenues for future vulnerability reduction efforts.

Signature Reduction The air mixer concept for reduction of engine exhaust plume infrared radiation, as part of a series of experimental hardware, was tested during an extensive program to eventually reduce the IR signature of Army aircraft. Other IR reduction efforts were aimed at the aircraft's own weapon system. For example, the temperature profiles of the 20mm XM-95 weapon were developed and translated into IR levels under various firing and airflow conditions, for use in establishing the requirement of IR shielding and provide the basic data necessary for design of these items.

MISSION SUPPORT

Mission support technological development effort is directed towards that equipment which will enhance the effectiveness of military operational capabilities of Army aircraft, particularly in the forward areas. This effort is conducted by the Eustis Directorate. A technical discussion of the major FY 75 accomplishments follows.

Operational Effects on Aircraft – A helicopter ice protection program was initiated in July 1973 for the development of an advanced anti-/de-icing system for Army helicopters, present and future. After a thorough review of meteorological data and past technology, design criteria were established and trade-off analyses were performed to quantify the penalties imposed by various types of ice protection concepts for Army aircraft under various icing severity level criteria. Penalties considered included aircraft design parameters such as gross weight, payload, performance, reliability, maintainability and cost. As a result of this effort, the cyclic electrothermal rotor blade de-icing concept was determined to be the most promising of known concepts for application to Army helicopters. Such a system has been designed, fabricated and applied to an experimental UH-1H helicopter for flight testing under simulated and natural icing conditions. Simulated icing testing conducted to date has demonstrated conceptual feasibility. Results of trade-off analyses indicate that cost and weight penalties associated with this concept of helicopter ice protection are significant. Additional programs have been established in an effort to identify, evaluate and develop helicopter ice protection system concepts with reduced penalties. Completed work has formed a basis for the design and testing requirements for Army helicopter ice protection systems to ensure maximum efficiency and minimal penalties and life cycle costs.

Aerial Delivery and Cargo Handling – The application of advance materials (Kevlar 29) to the family of slings developed in a prior year effort is being validated in a laboratory test program. For the 10,000 pound sling assembly it has been established that this material with appropriately designed terminal fittings will effect a 50% reduction in system weight over the developed sling assembly. Specimens in a 7 x 19 cable construction and in a parallel lay rope construction with potted terminal fittings have been obtained for fatigue, environmental and simulated operational testing.

Army aviation mid-intensity warfare doctrine for the high air defense threat environment envisions utilization of helicopters in supply/resupply missions requiring terrain following flight profiles, including nap of the earth flight. This new doctrine represents a major departure from current techniques and it will require the exploration of innovative approaches to allow expeditious delivery of internal and external loads. In coordination with appropriate TRADOC agencies, a program was initiated for concept(s) studies to determine best approaches toward accomplishment of helicopter transport of supplies in the high air defense environment requiring terrain following flight profiles. Concepts for rapid delivery of both internally and externally transported loads will be considered.

AIRCRAFT SYSTEMS SYNTHESIS

Aircraft Systems Synthesis project has as its objective, the generation of a unified, coordinated research and development program responsive to Army aviation system requirements and major thrusts. The overall approach involves:

- Ascertaining the needs and requirements of advanced airmobile systems.
- Conducting airmobile technology assessment with technological forecasting.
- Providing continual analysis and assessment of technological risks to identify technological voids.
- Effecting a balance RDT&E program via systematic resource allocation scheme.

This work is primarily accomplished at the Headquarters, AMRDL by the Advanced System Research Office and the Systems Research Integration Office with some preliminary design support from the Eustis Directorate.

There are four major areas of effort in this program. Brief technical descriptions of the major FY 75 accomplishments for the four areas of efforts are presented in Table V.

AIRCRAFT WEAPON TECHNOLOGY

The Army aircraft weaponization program provides the capability of delivering ordnance to destroy, neutralize, or suppress those targets jeopardizing ground or airborne forces in the conduct of the land combat role. This capability depends on the adequacy and timeliness of the aircraft weapons technology. Within the AVSCOM mission requirement to develop aviation systems, including the interface of aircraft subsystems and aerial armament subsystems, AMRDL has the responsibility to advance the technological base for aircraft weaponization applications. Primary performing Army activities for R&D of aerial armament subsystems include the ARMCOM and MICOM.

TABLE VI. AIRCRAFT SYSTEMS SYNTHESIS MAJOR FY 75 ACCOMPLISHMENTS

AREAS OF EFFORT	FY '75 ACCOMPLISHMENTS
EVALUATION OF ADVANCED AIRCRAFT CONCEPTS	DEVELOPED COMPUTERIZED DESIGN/EVALUATION PROGRAM FOR ESTIMATING VEHICLE PERFORMANCE. APPLIED PERFORMANCE TECHNIQUE TO OH-58, BO-105 AND OH-6 HELICOPTERS AS CANDIDATES FOR ASH. APPLIED PRELIMINARY DESIGN ENGINEERING TO STARS-V AND TO COMPARATIVE STUDIES OF TILT ROTOR AND PURE HELICOPTER.
ANALYSIS OF ARMY AVIATION R&D PROGRAMS	COMPLETED FOLLOWING RISK ASSESSMENTS: TILT ROTOR RESEARCH AIRCRAFT T-700 ENGINE HELLFIRE WEAPON SYSTEM AH-1/UH-1 ROTOR SYSTEM REMOTELY PILOTED VEHICLE AMC RESEARCH SIMULATORS CH-47 TRANSMISSION ASH ALTERNATES MODEL 540 ROTOR BLADE DEBOND
ORDERLY PLANNING & PROGRAMMING OF ARMY AVIATION R&D	CONDUCTED R&D SIMULATOR SURVEY. COMPLETED 4TH EDITION OF ARMY AVIATION RDT&E PLAN. PUBLISHED LABORATORY SPF/SPEF REPORTS. PUBLISHED 1ST EDITION OF LABORATORY PROJECT SELECTION PROCESS METHODOLOGY.
FOCAL POINT FOR ARMY AIRMOBILE R&D	EVALUATED INDUSTRIAL AND UNIVERSITY IR&D PROPOSALS. PARTICIPATED IN RPV LITTLE "r" PROGRAM SOURCE SELECTION. REVIEWED TILT ROTOR STRUCTURAL AND PROPULSIVE SYSTEMS.

AMRDL's overall approach to this project is to ascertain advanced aircraft weaponization concepts and technology voids, structure a program to advance critical technologies, and demonstrate subsystem/component feasibility. Three major areas of aircraft weapon technology are discussed below.

Gun and Mount – Probability of hit/kill of an aerial weapon system can be improved through precise weapon pointing incorporating improved control systems and where necessary, short term stabilization. Work in this area has been devoted to the development of linear and non-linear mathematical models of the XM-97 for development of constant recoil techniques. One such constant recoil mechanism has been mated to an impulse generator, mounted on a hard stand, instrumental, and fired. Preliminary results indicate satisfactory operation of the impulse generator and burst firing was attained with the constant recoil device in place. Another major effort in this field was the development of a screening model for the purpose of evaluating improvements in system performance from the incorporation of various proposed subsystem modifications to the baseline AH-IG/MWFCS.

Fire Control – Fire control R&D includes improved night/all-weather target acquisition devices, and fire control parameters to demonstrate feasibility of automatic target detection, recognition, and tracking. Breadboard hardware for a cuer system was fabricated and successfully passed acceptance system testing. Also, the data correlation and reduction portion of the error source study involving MWFCS integrated with the 20 mm turreted XM-197 has been completed. Utilizing the MWFCS (XM-127) mounted on the aircraft nose and integrated with the 20 mm turreted weapon (XM-197), figure 27, error sources affecting the accuracy of the weapon system have been instrumented and recorded via various sensors and devices; e.g., wind sensor above the MWFCS, camera below the XM-197 gun, and processor and recording equipment mounted below the wing stubs. The data will be applied to system improvements in future conventional aircraft turret/gun systems, validation of existing airframe/weapon systems model, and providing a basis for evaluating closed loop system concepts.

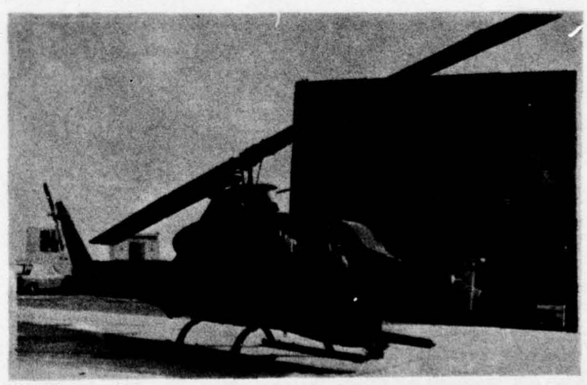


Figure 27. Multi-Weapon Fire Control System testbed instrumented for error budget test.

Aerial Munition – Expansion of the technology base in aerial munitions is achieved by works in munition drag reduction via the fumer concept, in kinetic energy penetrator, and in shallow-cone shaped-charge. Experimental and analytical investigation of fumer compositions demonstrated that base drag reduction of up to 70% can be accomplished. For the penetration analysis, approximately 1000 ballistic limits for 125 different projectile types have been gathered, and a number of predictive equations have been obtained. In shallow-cone shaped-charge (SCSC), the effects of spin on the formation of the jet penetrator have been studied using a hydrodynamic version of HEMP. A model was developed which shows the expected dependence of spin effects on liner angles. Additionally, for the 2.75-inch Rocket System, the placement of submunitions into a target area can be facilitated when appropriate drag devices are properly incorporated into each submunition. Ejection, dispersion, and ground pattern characteristics of drag devices have been successfully tested at various altitudes and ejection velocities.

ADVANCED TECHNOLOGY DEMONSTRATION – PROGRAM CATEGORY 6.3

TILT–ROTOR RESEARCH AIRCRAFT

The Tilt-Rotor Research Aircraft Project, a joint Army/NASA program, will lead to a complete flight demonstration of the tilt-rotor concept and an evaluation of tilt-rotor capabilities with respect to mission performance, survivability, and safety.

On 1 August 1973, a contract was awarded to Bell Helicopter Company (BHC) for design, fabrication, and testing of the two XV–15 Tilt-Rotor Aircraft. The final Design Review was held on 12 December 1974, and all drawings were released during the first half of 1975. During the year a Risk Assessment was prepared and released, also a Revised Project Plan and an Updated Familizarization Manual depicting the aircraft configuration were issued. Extensive test planning is now underway and some component testing has been initiated. The fuselage structure (figure 28) for No. 1 aircraft has been completed and system installations are underway. Many other components, including the AFCS, engines, and major wing and blade components have been completed. During September 1974 BHC commenced work on modifying and refurbishing the 25 foot tilt rotor and controls for powered tests in the Ames 40x80 Foot Wind Tunnel, figure 29. These tests, which are scheduled to be conducted in late 1975, will explore autorotation characteristics and expand the previously tested pylon conversion boundaries. Rollout of the first XF-15 will occur early in 1976 and will be followed by extensive ground testing. First flight is scheduled for 1977.

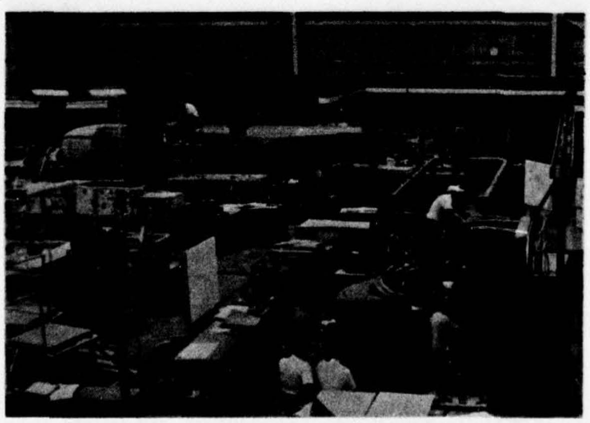


Figure 28. Overview of XV-15 fuselage/empennage assembly area.

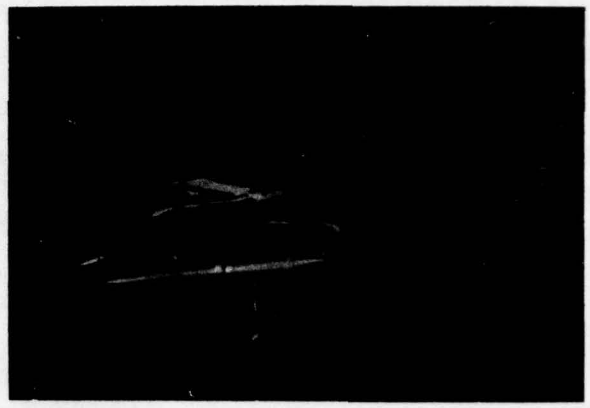


Figure 29. Tilt-rotor model installed in Langley Wind Tunnel.

ROTOR SYSTEM RESEARCH AIRCRAFT

This joint Army/NASA program will provide in-house research capability to evaluate the potential of promising new advanced rotor concepts, as well as verification of numerous areas of supporting research and technologies. Sikorsky Aircraft has essentially completed the design of the aircraft except in two areas which are undergoing some re-direction. First, analysis and simulation studies utilizing wind tunnel data indicated the need for a fail-operational stability augmentation system to ensure flight safety. Second, extensive analysis of the rotor Active Isolation/Balance System (AI/BS) indicated that changes were desirable in the proposed configuration in order to enhance the adaptability of the AI/BS to a wide range of advanced rotors. The additional design effort required for these two important systems will result in approximately a five month slip in the original aircraft delivery schedule. First flight of the RSRA is scheduled for July 1976. An artist concept of the RSRA is shown in figure 30.

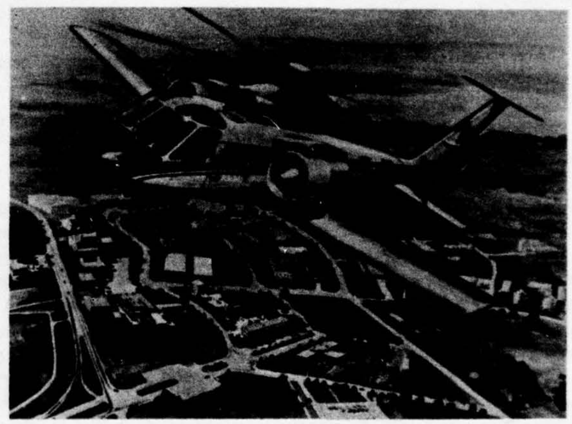


Figure 30. Artist concept of Rotor System Research Aircraft.

ADVANCING BLADE CONCEPT

The Advancing Blade Concept (ABC) is an aircraft equipped with a coaxial, counterrotating, hingeless rotor system, which offers several potential advantages over conventional rotor systems. With this concept, it is anticipated that the problems of retreating blade stall will be largely eliminated and maneuver capability significantly enhanced. Substantial improvements in maintainability are projected for this concept, since the need for a tail rotor is eliminated and the main rotors are hingeless. The program is under

contract to Sikorsky Aircraft and the aircraft configuration (XH-59A) is shown in figure 31.

The aircraft was involved in an accident in August 1973. A comprehensive accident investigation was conducted which revealed rotor inflow induced pitch-up tendencies at low advance ratio. The program was restructured with resumption of flight testing of the ABC configuration as a helicopter with a modified flight control system. Ground tests, wind tunnel tests, and analytical studies will also be made to further investigate and substantiate the flight worthiness of the test aircraft. The flight test program of the ABC aircraft with modified controls was initiated on 21 July 1975 with a short hover flight.

Figure 31. XH-59A configuration.

ADVANCED AIRCRAFT STRUCTURES

Development of advanced aircraft structures are conducted by the Eustis Directorate. The major FY75 accomplishments are:

Advanced Fuselage Structure – A full-scale flightworthy, all-composite tail section (figure 32) for an AH-1G helicopter was fabricated utilizing filament winding methodology and subjected to laboratory static and fatigue testing. Static deflection and dynamic response measurements were made. The tail section was then subjected to a fatigue load spectrum at 60% of design limit load for 270,000 cycles. Conservative estimates indicate that these fatigue cycles/load levels are well beyond those that established the metallic fuselage operational life.

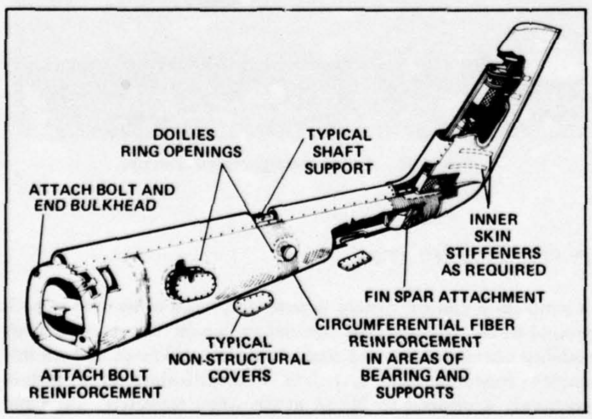


Figure 32. Composite structure tail boom.

Advanced Composite Shafting – Three advanced composite, impact-resistant drive shafts have been designed and fabricated. The designs consist of a filament-wound graphite with impact-resistant epoxy resin, a graphite/epoxy prepreg tape with an impact-resistant cover of lightweight foam stabilized flexcore and heat shrink Mylar film, and a sandwich wall construction with Kevlar/graphite/epoxy skins and a thin syntactic foam core (see figure 33). The shafts have been subjected to fatigue, ballistic and low-velocity impact tests with the following results:

- Fatigue requirements were met by all configurations.
- Graphite/epoxy configuration failed following .50 cal and fully tumbled .30 cal ballistic impacts, and low-velocity impacts.
- Filament-wound graphite and sandwich wall construction configurations failed following a severe-fully tumbled .30 cal impact but exceed requirements for .50 cal ballistic impacts and low-velocity impacts.

After analysis of the results of this program, design concept incorporating the best features of the previous effort will be pursued through full-scale flight test.

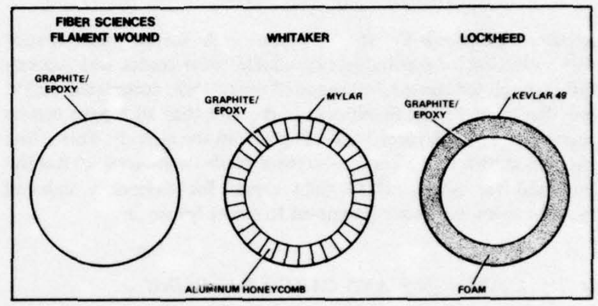


Figure 33. Advanced composite shafting.

PROPULSION

Validation of propulsion and drive train components, fabricated as assemblies and including rig and flight testing, comprise the 6.3 Propulsion efforts. These activities are conducted by the Eustis Directorate.

Small Turbine Advanced Gas Generator – This program has as its objective the establishment of a gas generator development program which provides the technology for advanced aircraft engines and auxiliary power units in the range of 200 horsepower to 800 horsepower. The technical objectives comprised improvements in specific fuel consumption of 20 percent to 30 percent, and increases in specific horsepower of 35 percent to 45 percent relative to current production engines. Four contracts have been initiated, and testing to date has demonstrated that the technical objectives have been met or surpassed.

RELIABILITY AND MAINTAINABILITY

The objective of 6.3 R&M effort is to provide comprehensive component and system reliability and maintainability credibility by validating improved R&M designs, test and acceptance criteria. The Eustis Directorate conducts the 6.3 R&M programs.

Rotor Isolation – All design, fabrication and ground testing has been completed with flight tests scheduled to commence on a dynamic anti-resonant vibration isolator (DAVI) applied to the transmission of a UH-1 aircraft. The program objective is to demonstrate feasibility and the improvement in helicopter reliability and maintainability achievable through vibration isolation. The system has inherent mechanical simplicity, light weight, and is passive, requiring no external power or signal conditioning equipment. A UH-1H was selected for demonstration of the

principal as it represents a very difficult case to isolate, and removal of the present in-plane system provides the needed space to mount the isolators. The system consists of four transmission mounted units and one lift-link unit and weighs approximately 132 pounds. Nearly 100% isolation of 2/rev vibration will be accomplished. A simple schematic diagram of the system is shown in figure 34.

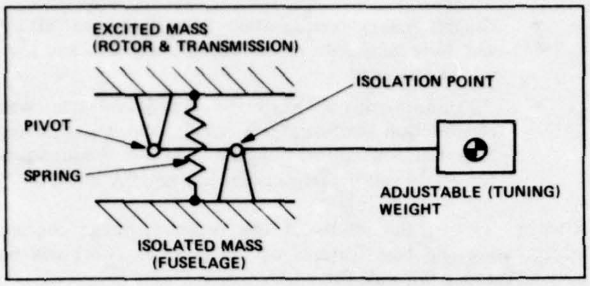


Figure 34. Schematic diagram of DAVI.

Repairable/Expendable Rotor Blades – A formal maintenance demonstration of repairable/expendable rotor blades was successfully completed showing all required repair tasks completed within specified time limits. Significant is the fact that all repairs can be accomplished with rotor blades in place on the aircraft. This effort has also shown that a composite rotor blade (non-metallic) has the potential for nearly 100% field repair for externally induced failure modes, eliminating removal to depot for repair.

AERIAL DELIVERY AND CARGO HANDLING

The primary objective of this effort is to determine the effectiveness of new concepts and designs of aerial delivery and cargo handling equipment. The near-term programs, conducted by the Eustis Directorate, center on cargo acquisition and stabilization.

Cargo Acquisition – The technical feasibility of a fully automated container top-lift device for a Mil-Van container without the assistance of ground personnel during hookup and release has been demonstrated. Figure 35 is a flight demonstration of the top-lift device on the Army/Boeing Model 347. This program is now in the design stage for a militarized, flight worthy version of the demonstration configuration. The program includes fabrication and testing for operational validation.

Figure 35. Flight demonstration of top-lift device for MIL-Van container.

Cargo Stabilization – The Active Arm Load Stabilization System (AALESS) has been demonstrated to substantially dampen pendular and yaw oscillations of an externally slung helicopter load and also eliminated pilot induced oscillations frequently experienced during IFR conditions with an external load. The AALESS basically consists of two, longitudinally separated, power-activated rigid pendants attached beneath the helicopter, from which the load is suspended. Feedback from the load position initiates corrective pendant movement, which damps undesirable aerodynamically induced load motions.

The breadboard test configuration has been redesigned, AALESS II, a complete system fabricated, bench tested, and released for flight evaluation on a CH-47C helicopter.

REMOTELY PILOTED VEHICLES

The Aquila Remotely Piloted Vehicle (RPV) Program, formerly called the little "r" program, is being funded through the Weapon Systems Manager at AVSCOM and contracted through AMRDL. This system will enable the TRADOC to evaluate the capabilities of mini-RPVs through "hands on" testing so that a ROC can be established if warranted. The following surveillance and target acquisition/designation capabilities will be examined (1) broad area surveillance via unstabilized TV; (2) photo reconnaissance; (3) target acquisition; (4) target location and artillery adjustment; and (5) target designation. Significant features of Aquila include: automated modes (waypoint guidance, link loss, dead reckoning, and automatic search modes), launch and recovery from unimproved sites, a range of 20 km, gross weight of 120 pounds, payload of 30 pounds, and endurance in excess of 1-½ hours. This is the first Army program utilizing a Letter of Agreement (LOA) management structure between the developer and user commands. Delivery of the first Aquila system to the Army is scheduled for December 1975. The configuration concept of Aquila is shown in figure 36.

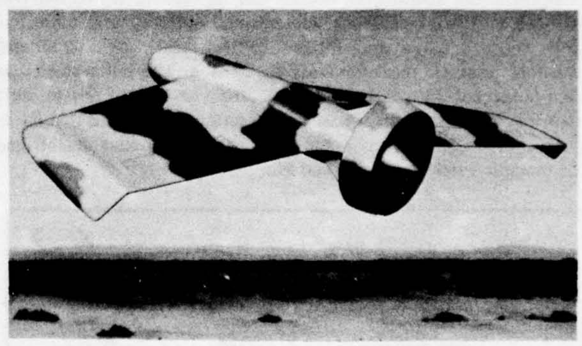


Figure 36. Aquila configuration concept.

IN-FLIGHT SIMULATOR

A simulation control system is being developed to be used in both ground-based and in-flight simulators which can vary aircraft stability characteristics and simulate various guidance and control display concepts. The system is a modification of a system previously developed by NASA at the Ames Research Center and designated V/STOLAND. The system is being installed in a UH-1H helicopter and will be used to evaluate ground-based simulator results as well as providing a variable stability flight platform for development of various control system and display concepts. Figure 37 shows the flight instrument panel and control console of the system installed in the UH-1H.

Figure 37. In-flight simulator instrument panel.

Figure 39. Bell YAH-63 prototypes.

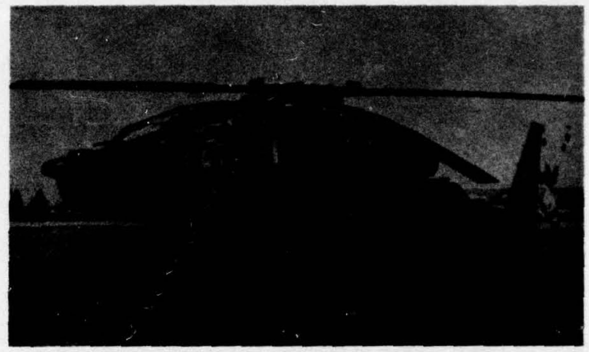


Figure 40. Hughes YAH-64.

LABORATORY SUPPORT ACTIONS – PROJECT/PRODUCT MANAGERS AND OPERATIONAL SYSTEMS

ADVANCED TECHNOLOGY ENGINES

The Laboratory is providing technical support for the development of the T700-GE-700 engine, figure 38. The UTTAS-PM has the total development responsibility for this engine which will be used to power both the UTTAS and the AAH aircraft (see figures 39, 40, 41 and 42). The T700 is a direct outgrowth of the AMRDL's 1500 SHP Demonstration Engine Program. Since initiation of development testing in February 1973, the engine has accumulated over 8,400 test hours while meeting all objectives. Both XT and YT engines have been delivered to both UTTAS and AAH airframe manufacturers.

Figure 41. Boeing-Vertol UTTAS prototypes.

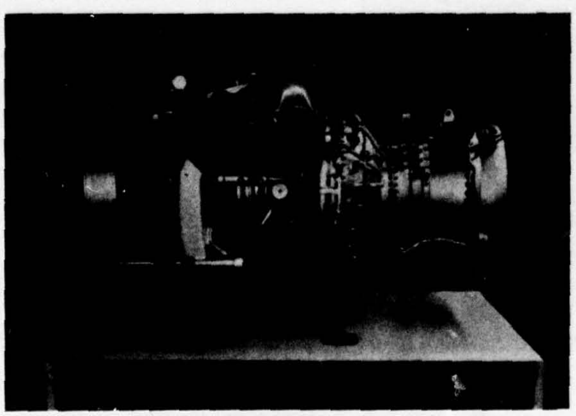


Figure 38. T700 advanced technology engine.

Figure 42. Sikorsky UTTAS prototypes.

HEAVY LIFT HELICOPTER

The Heavy Lift Helicopter (HLH) Advanced Technology Components (ATC) program began in June 1971. It includes the efforts to design, develop, fabricate; test and demonstrate the critical dynamic ATC components/systems consisting of:

- Rotor/Drive System
- Flight Control System
- Cargo Handling System

These systems, under development, are shown in figure 43.

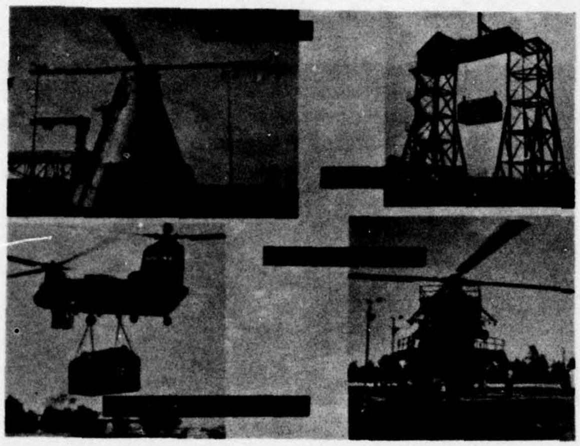


Figure 43. Army/Boeing HLH Advanced Technology Components.

In January 1973 the program was modified to provide for the design, development, fabrication, and test and evaluation of one HLH Prototype Aircraft. With the exception of the engine programs and the Systems Engineering effort, AMRDL provides technical management of the ATC/Prototype program for the HLH Project Manager.

The ATC flight control system feasibility demonstration was completed in October 1974. The basic stability and control augmentation features were integrated with the fly-by-wire system with excellent results. Preliminary data indicates that the precision hover, load stabilization and automatic approach to hover modes are feasible. A total in excess of 2000 hours of integrated ground test rig and 250 hours flight test time have been accomplished in the performance of this task.

ADVANCED SCOUT HELICOPTER

The Laboratory provided technical support to both the Advanced Scout Helicopter Task Force and the Advanced Scout Helicopter Special Study Group in the development of the Concept Formulation packages for this proposed air mobility system. In addition to supplying the Deputy Technical Chief, responsible for the preparation of the ASH Tradeoff Determination reports, the Laboratory provided all study inputs relative to aircraft design and performance, propulsion, structures, agility, reliability and maintainability, and safety and survivability. More than 200 point aircraft designs were developed to illustrate the impacts of mission requirements, mission equipment packages, number of engines, engine and structures technologies, and ASE considerations.

AH-1Q IMPROVED MAIN ROTOR BLADES

In October 1974, contracts were awarded by AMRDL acting for the Cobra PM to Bell, Hughes, and Kaman for the design of an improved main rotor blade for the AH-1Q helicopter. Primary purpose was to investigate the feasibility of improving hot day hovering performance through the use of new airfoils and changes in blade planform and/or twist. In addition, survivability with regard to ballistic damage was to be improved. Key design considerations include radar reduction, R&M characteristics and cost. These improvements were to be obtained with no detrimental effects on forward flight, blade and hub characteristics, stability and control, and blade weight. The study program indicated that an approximate 6% improvement in hover performance over the existing rotor could be achieved while also improving forward flight performance. In early May 1975, a contract was awarded by AVSCOM to Kaman for the detail design fabrication, qualification flight test and integration of an improved composite main rotor blade for the AH-1Q helicopters.

ACTIVITY INDICATORS

PUBLICATIONS

During FY 75, AMRDL originated a total of 161 reports, papers, and presentations. The total number of reports was 87, of which 56 were prepared (entirely or in part) by AMRDL employees and 31 were published under contracts. Reports which originated at Ames, Langley, or Lewis Directorates bear NASA report numbers, while those originated at Eustis Directorate bear AMRDL numbers. A complete listing of these publications and presentations is contained in Appendix C.

HONORS AND AWARDS

Dr. Fredric H. Schmitz and C. Rande Vause, engineers with the Ames Directorate received the Army Research and Development Achievement Award which included a citation, plaque and medallion. The two engineers developed an award winning technique which enables heavily loaded helicopters to get off the ground in a much shorter take-off area. The new take-off technique has applications for commercial as well as military use.

The National R&D Award Plaques are displayed in figure 44 after presentation ceremonies conducted by Lt. Gen. John R. Deane, Jr., at that time deputy Chief of Staff for Army Research Development and Acquisition and now Commanding General, Army Material Command.

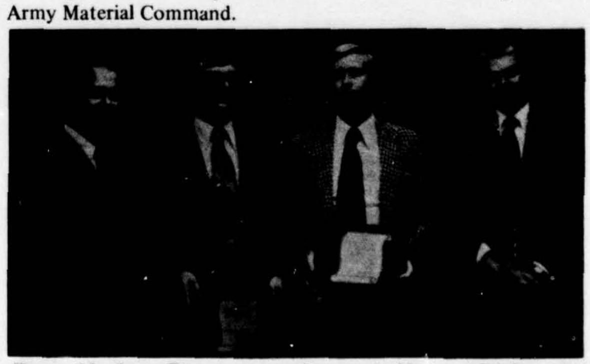


Figure 44. Ames Directorate engineers win National R&D Award (from L to R in photo is Gen. Deane, Dr. Schmitz, Mr. Vause, and Dr. Hans Mark, Director of Ames Research Center).

Dr. Irving C. Statler, Director, Ames Directorate, was elected to a two-year term as Chairman of the Flight Mechanics Panel at the panel's 45th meeting held in Paris France, October 18. This panel is one of eight technical panels of the Advisory Group for Aerospace Research and Development (AGARD), North Atlantic Treaty Organization (NATO).

For his paper "Helicopter Ground Resonance Analysis in Light of Army Requirements," given at the U.S. Army 1974 Science Conference, Dr. Charles E. Hammond of the Langley Directorate was awarded a certificate and bronze medal from the Chief of Research and Development. In addition, Department of the Army Incentive Awards Board approved a special cash award.

Dr. John D. Hwang, AMRDL Headquarters has been appointed the Chairman of the Operations Research Subcommittee of the Army Mathematics Steering Committee. Under his leadership, the Subcommittee is conducting an in-depth study of the requirement and specific recommendations for various so-called retail computing issues.

Thomas L. Coleman, Director, Langley Directorate, served as the Laboratory representative on the 1974 Army Scientific Advisory Panel (ASAP) Summer Study. The panel convened at Fort Monroe 15-26 July 1974. Mr. Coleman participated in two Mission Area Deficiencies and Opportunities subgroups. They were Battlefield Surveillance and Target Acquisition and Mobility Enhancement and Denial. Mr. Coleman has also been appointed as National Leader for Technical Panel HTP-4 Helicopter Operations Technology, the Technical Cooperation Program.

The American Helicopter Society was represented by the following AMRDL personnel:

- Dr. Richard M. Carlson – Director at Large
- Andrew W. Kerr – Western Region Vice President
- Frederick H. Imman – Chairman, Structures & Materials Committee
- Leroy T. Burrows – Chairman, Propulsion Committee
- Leroy H. Ludi – Chairman, Operations and Testing Committee

In addition the Laboratory was represented on the following Technical Committees:

- Aerodynamics – 3 members
- Aircraft Design – 2 members
- Dynamics Technical – 2 members
- Handling Qualities – 3 members
- Manufacturing & Product Assurance – 1 member
- Operations & Testing – 2 members
- Propulsion – 1 member
- Structures & Materials – 3 members

PATENTS

Wayne A. Hudgins of the Eustis Directorate, was awarded a patent on a Shaft Seal, 19 November 1974. This new development is a sealing apparatus for use in gearbox-transmission systems - which contain fluids miscible with ferrofluids. A ferrofluid seal is combined with a controlled clearance (Labyrinth) seal and a pressurized air cavity, the ferrofluid seal providing the external seal and the controlled clearance seal and the pressurized air cavity preventing the internal fluids from contacting the ferrofluids.

OTHER ACTIVITIES

In a unified research effort coordinated through the NASA-Ames and the NASA-Langley Research Centers, the Ames and Langley Directorates hosted an Army/NASA Industry Symposium on Rotorcraft 19-21 November at Langley Research Center. The purpose of the symposium was to apprise industry of the Army/NASA rotorcraft research programs in the following areas: Aerodynamics, Dynamics and Aeroelasticity, Stability and Control, Structures and Materials, Acoustics, and Advanced Rotor Concepts. In addition, both the Rotor Systems Research Aircraft and the Telescopic Rotor Aircraft status briefings were included. Industry panels were provided the opportunity to present prepared commentary on each of the topics presented. The symposium was well attended and well received by industry representatives.

The US Army Air Mobility R&D Laboratory is well represented on governmental and nongovernmental, technical and scientific committees of both national and international stature. The following is a listing of the organizations in which employees of the Laboratory participate as officers and/or members:

- Technical Committees of the American Helicopter Society
- Technical Committees of the American Institute of Aeronautics and Astronautics
- Technical Committees of the American Society of Mechanical Engineers
- Technical Committees of the American Society of Civil Engineers
- Government-Industry Committee of the Society of Aeronautical Weight Engineers
- Technical Committees of the Society of Automotive Engineers
- Technical Committees of the National Bureau of Standards
- Society of Experimental Test Pilots
- American Mathematical Society
- American Psychological Association
- American Gear Manufacturer Association
- Panels and Working Groups of the Advisory Group for Aerospace Research and Developement (AGARD) of NATO
- Committees of the Environmental Control Agency
- Committees of the National Materials Advisory Board
- Research and Technical Advisory Committee on Materials and Structures of NASA
- Technical Committees, Technical Working Groups and Advisory Groups of the Defense Atomic Support Agency, Deparment of Defense, Department of the Army, and Department of the Navy

SPECIAL ITEM

Paul F. Yaggy, Director of the US Army Air Mobility Research and Development Laboratory, AMRDL/Ames Research Center, Moffett Field, California retired from the Federal Service on 30 September 1974 after more than 31 years of continuous service.

Mr. Yaggy, named the first Director of AMRDL when it was established in 1970, was a key figure in the development of the organization which featured a unique interagency relationship of three of its four Directorates with the National Aeronautics and Space Administration's research centers.

Mr. Yaggy was honored at a retirement dinner attended by nearly 250 friends and associates including his mother and father, the Reverend and Mrs. Van Clief Yaggy. Other distinguished guests included General Ferdinand J. Chesarek, former Commanding General, Army Material Commander who served as Master of Ceremonies; US Representative Norman Y. Mineta, 13th District, San Jose; Dr. Hans Mark, Director, NASA/Ames Research Center; Dr. Robert B. Dillaway, former AMC Deputy for Laboratories and now AMC Chief Scientist; Major General Frank H. Hinrichs, Commanding General, Army Aviation Systems Command; and the Mayor of the City of Santa Clara, (figure 45).

Figure 45. AMRDL Director retires (from L to R in photo is Paul Yaggy, Gen. Hinrichs, and Mrs. Yaggy).

FACILITIES

The facility complex available to the Laboratory is unique within the Government. It represents a special blending of both Army and NASA facilities which can be utilized to meet the R&D needs of the Army as well as the overall aviation community. The major facilities that are available to the Laboratory are indicated in Table VII.

TABLE VII. MAJOR FACILITIES AVAILABLE FOR R&D

COMBUSTION RESEARCH FACILITY
COMPONENT RESEARCH LAB
ENGINE RESEARCH FACILITY
ENVIRONMENTAL TEST FACILITY
FLIGHT RESEARCH FACILITIES
GROUND BASED SIMULATION FACILITIES
HEAT TRANSFER FACILITY
ILLIAC IV
LUNAR LANDER FACILITY
MATERIALS LABORATORY
STRUCTURES RESEARCH LAB
STRUCTURES TESTING LAB
VULNERABILITY TESTING LABORATORY
WHIRL TOWER FACILITY
WIND TUNNELS
ACOUSTICAL TEST FACILITY
CARGO HANDLING SYSTEM INTEGRATED TEST RIG

Of the facilities indicated, those that impinge directly on current critical Army needs coupled with the Ames and Langley wind tunnels provides a balanced research base for a logical synthesis of aeronautical concept through evaluation. Specifically, the Ground Based Simulation Facilities are being utilized to study and evolve techniques for flying helicopters in the nap-of-the-earth mode. The Flight Simulator for Advanced Aircraft and the Six-Degree-Of-Freedom Simulator are two such facilities, with the latter shown in figure 46.

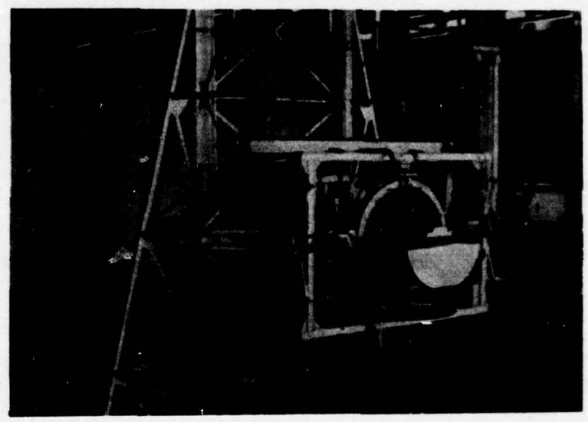


Figure 46. Six-Degree-of-Freedom Simulator.

Additional facilities that actively engaged in present R&D efforts are briefly described below.

AERODYNAMIC/ACOUSTIC ROTOR TEST CHAMBER

This facility consists of an 800 sq. ft. test chamber and a two-story control room. The test chamber is acoustically treated with foam wedges, figure 47, with the air inlet area at the top of the test chamber is acoustically treated to attenuate noise and isolate inlet flow from external winds. The test chamber has a vertically movable platform/rotor wake ejector system and an acoustic wedge platform.

Test rotors up to 8 feet in diameter can be operated in the center of the chamber. Air is drawn in through the acoustic inlet and the wake is captured by the movable platform ejector system and ducted out of the chamber through two 10-foot doors on each end of the chamber. Both rotor aerodynamic performance and acoustic signature can be measured on hovering rotors.

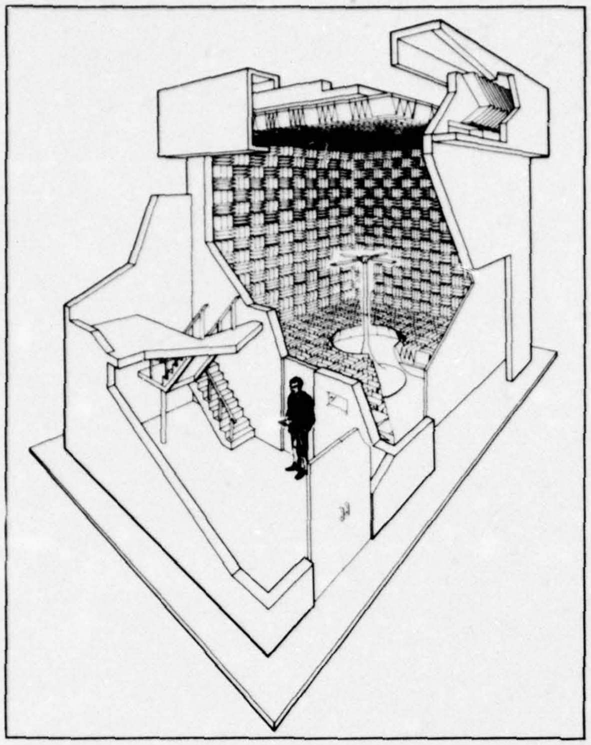


Figure 47. Cut-away view of Aerodynamic/Acoustic Rotor Test Chamber.

WATER TUNNEL

The 21- by 31-cm Water Tunnel is a variable pressure, variable speed, closed circuit test facility. A view of the tunnel and supportive equipment is shown in figure 48, and a typical airfoil installation featuring hydrogen bubble flow visualization is shown in figure 49.

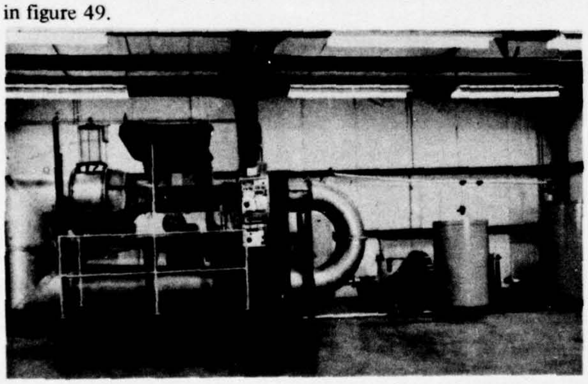


Figure 48. Front view of Water Tunnel.

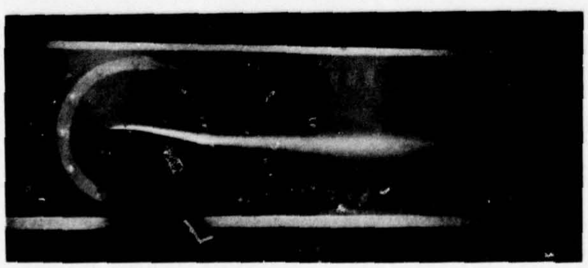


Figure 49. Hydrogen bubble flow visualization in Water Tunnel.

The water is circulated by a three bladed impeller which is turned by an SCR controlled 20 horsepower DC motor. A feedback control system capable of reducing the tunnel speed variation by a factor of ten can be used during unsteady tests. Before entering the test section, the flow passes through two sections of honeycomb, four screens and a 3.2:1 contraction.

The test model is supported on a mechanism designed to deliver a sinusoidal pitch amplitude accurate to within 0.5 percent. A separate SCR controlled DC motor regulates the frequency of pitch.

Electrodes mounted on the model surface in conjunction with a 0 to 50 volt DC power supply produces electrolysis to form hydrogen bubbles for flow visualization markers. A xenon flash lamp mounted above the test section illuminates the flow field for photographic purposes, and can be synchronized at any given phase angle.

This facility has been primarily used for visualization and photographic documentation of flows about oscillating airfoils. Instrumentation exists for recording tunnel velocity, model angle of attack and pitching moment, and the phase angle at which the flash lamp is synchronized.

CARGO HANDLING TEST FACILITY

In coordination with Headquarters AVSCOM, office of the PM-HLH, accountability for the HLH Cargo Handling Test Facility (ITR) has been transferred to the Eustis Directorate. The ITR (figure 50) has a dual mode suspension capability, has demonstrated load application in excess of 70 tons, and provides a unique capability responsive to present and foreseeable R&D efforts and to the verification/application of technological and state-of-the-art advances in this testing parameter.

Preliminary coordination with TRADOC indicates a significant potential for the facility as an initial training device for helicopter load controlling crewmen in cargo handling operations and in the training of ground crews in rigging procedures.

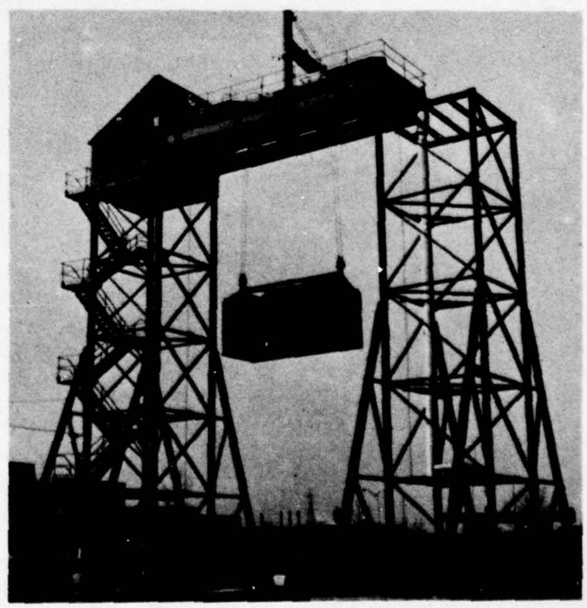


Figure 50. Cargo Handling System Integrated Test Rig.

APPENDIX A

Department of the Army

Statement of

A PEACETIME R&D STRATEGY

By

Assistant Secretary of Army (Research & Development)

Devote highest priority to preservation of the technological base (6.1, 6.2, 6.3a) at the present real dollar level in order to solve critical combat deficiencies and concentrate on improving the management and ROI thereof. The tech base comprises, from the material standpoint, much of the future strength of the Army and is the spawning ground of any major technological breakthrough.

As the next highest Priority, rely upon evolutionary development (product improvement) as the basic and most effective means of maintaining a quantitatively adequate force structure.

As the next priority, focus a limited number of all-new system developments in combat essential areas wherein quantum jumps in capability can be realized. Fully fund these programs to move through the acquisition process at an optimum pace even at the expense of the large body of other systems being pursued.

Concentrate remaining funds on the demostration, where possible in *hardware* form, of other promising components and systems.

Do not attempt to match USSR hardware in kind, but rather seek alternate means of circumventing and negating their strengths (e.g., do not attempt to match USSR on a tank-per-tank basis . . . but rather rely upon, say, anti-tank missiles to offset numerical disadvantages).

Avoid, where possible, applications of technology which result in extensive sophistication; instead seeking ingenuity of design and reductions in associated personnel costs. Quantitative force level considerations must be given *at least* equal attention with qualitative improvements.

Rely upon the technology of our allies to fill-out our own R&D efforts, achieving this through the mechanism of joint procurement rather than joint development.

APPENDIX B

US ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY

R&D PROGRAM FLOW DIAGRAMS

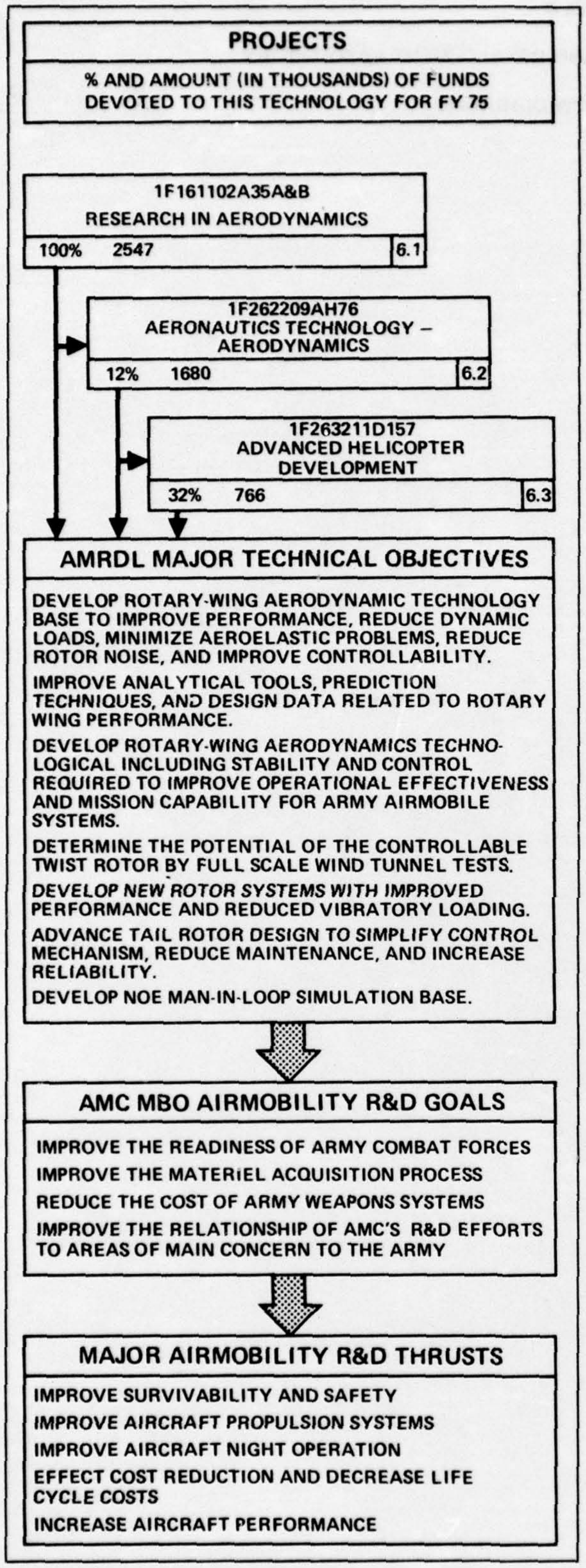


Figure B-1. Aerodynamics R&D program flow diagram.

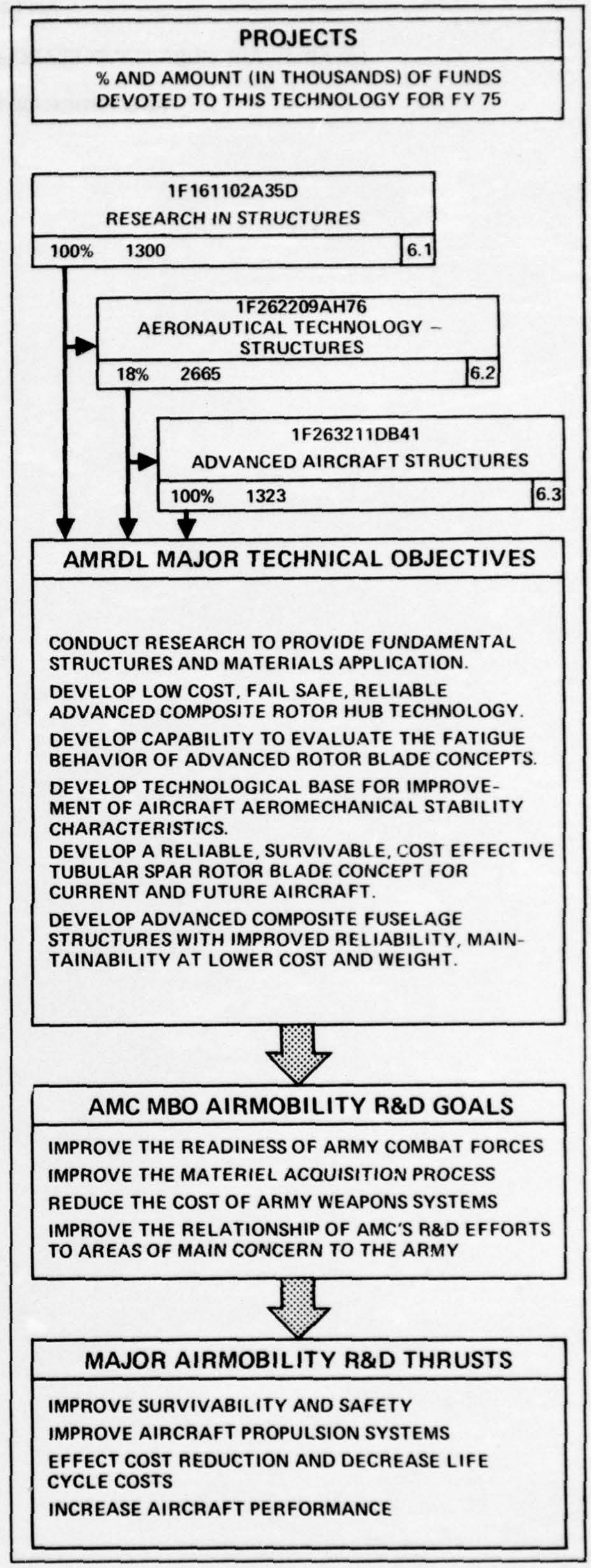


Figure B-2. Structures R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1G161102A35C
RESEARCH IN PROPULSION
100% 785 | 6.1

1F262209AH76
AERONAUTICAL TECHNOLOGY – PROPULSION
20% 2955 | 6.2

1G263201D447
DEMONSTRATOR ENGINES
100% 2.120 | 6.3

AMRDL MAJOR TECHNICAL OBJECTIVES

INCREASE LOAD AND SPEED CAPABILITY OF AIRCRAFT DRIVE TRAIN COMPONENTS WITHOUT INCREASING WEIGHT.

IMPROVE TECHNOLOGY FOR ADVANCED DESIGNS OF GEARS, BEARINGS, AND SEALS WITH FAVORABLE R&M CHARACTERISTICS.

DEVELOP REQUIRED UNDERSTANDING OF FLOW PHENOMENA PECULIAR TO COMPONENTS OF SMALL ENGINES.

CONDUCT RESEARCH ON HIGH-RISK/HIGH-GAIN CONCEPTS ASSOCIATED WITH SMALL, HIGH-SPEED ENGINES AND TRANSMISSIONS.

DEVELOP ADVANCED METHODS FOR TRANSMITTING TORQUE.

DEMONSTRATE A 20-45% IMPROVEMENT IN SMALL ENGINE PERFORMANCE WITH A SIGNIFICANT REDUCTION IN NUMBER OF ROTATING PARTS.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES
IMPROVE THE MATERIEL ACQUISITION PROCESS
REDUCE THE COST OF ARMY WEAPONS SYSTEMS
IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF MAIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY
IMPROVE AIRCRAFT PROPULSION SYSTEMS
EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS
INCREASE AIRCRAFT PERFORMANCE

Figure B-3. Propulsion R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1F262209AH76
AERONAUTICAL TECHNOLOGY – RELIABILITY & MAINTAINABILITY
14% 2040 | 6.2

1F263209DB38
RELIABILITY & MAINTAINABILITY
100% 927 | 6.3

AMRDL MAJOR TECHNICAL OBJECTIVES

DEVELOP ADVANCED DIAGNOSTIC-CONDITION MONITORING CAPABILTIY TO IMPROVE MAINTENANCE.

EVALUATE ADVANCED DESIGN CONCEPTS TO IMPROVE RELIABILITY AND MAINTAINABILITY OF ARMY AIRCRAFT.

CONDUCT OPERATIONAL EVALUATION OF BONDED FIELD REPLACEABLY ROTOR BLADE POCKETS.

CONDUCT DEMONSTRATION TESTS OF MOTOR VIBRATION ISOLATION SYSTEM INSTALLED ON UH-IH HELICOPTER.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES
IMPROVE THE MATERIEL ACQUISITION PROCESS
REDUCE THE COST OF ARMY WEAPONS SYSTEMS
IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF AMIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY
IMPROVE AIRCRAFT PROPULSION SYSTEMS
EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS
INCREASE AIRCRAFT PERFORMANCE

Figure B-4. Reliability and Maintainability R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1F262209AH76
AERONAUTICS TECHNOLOGY – SAFETY & SURVIVABILITY

14%	2092	6.2

AMRDL MAJOR TECHNICAL OBJECTIVES

IMPROVE CRASHWORTHINESS OF SEATING SYSTEMS AND AIRCREW RESTRAINT IN ARMY AIRCRAFT.

INVESTIGATE BALLISTIC TOLERANT FUEL TANKS FOR PROTECTION AGAINST 23mm HEI PROJECTILE THREATS.

REDUCE INFRARED RADIATION FROM ARMY AIRCRAFT TURBOSHAFT ENGINE EXHAUST PLUME.

DEVELOP STRUCTURAL DEFORMATION DATA APPLICABLE TO LARGE-SCALE AIRCRAFT IN THE CRASH ENVIRONMENT.

REDUCE THE VULNERABILITY OF THE AH-1G FLIGHT CONTROLS SYSTEM TO BALLISTIC IMPACTS BY DESIGNING A SURVIVABLE SYSTEM SUITABLE FOR QUALIFICATION AND APPLICATION TO SIMILAR TYPE AIRCRAFT.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES

IMPROVE THE MATERIEL ACQUISITION PROCESS

REDUCE THE COST OF ARMY WEAPONS SYSTEMS

IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF MAIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY

IMPROVE AIRCRAFT PROPULSION SYSTEMS

IMPROVE AIRCRAFT NIGHT OPERATION

EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS

INCREASE AIRCRAFT PERFORMANCE

Figure B-5. Safety and Survivability R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1F262209AH76
AERONAUTICAL TECHNOLOGY – MISSION SUPPORT

16%	2302	6.2

1F263209DB33
AERIAL DELIVERY & CARGO HANDLING

100%	255	6.3

AMRDL MAJOR TECHNICAL OBJECTIVES

DEVELOP TECHNOLOGY FOR THE HANDLING AND TRANSPORT OF MILITARY CARGO FOR ALL AREAS OF SUPPLY AND WITH PARTICULAR EMPHASIS ON OPERATION IN A HIGH AIR DEFENSE THREAT ENVIRONMENT.

DEVELOP ADVANCED GROUND SUPPORT EQUIPMENT TO ENHANCE THE EFFECTIVENESS AND SAFETY OF AIRMOBILE SYSTEMS DURING GROUND OPERATION.

DEVELOP CONCEPT FOR ANTI-ICING/DE-ICING OF ARMY HELICOPTER TO PROVIDE ALL-WEATHER CAPABILITY.

DEVELOP A COST EFFECTIVE PAYLOAD ACQUISITION SYSTEM WITH AIRCREW AND GROUND CREW SAFETY AS A PRIME REQUIREMENT.

IMPROVE INFLIGHT CARGO LOAD STABILIZATION AND HANDLING.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES

IMPROVE THE MATERIEL ACQUISITION PROCESS

REDUCE THE COST OF ARMY WEAPONS SYSTEMS

IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF MAIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY

IMPROVE AIRCRAFT NIGHT OPERATION

EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS

INCREASE AIRCRAFT PERFORMANCE

Figure B-6. Mission Support R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1F262209AH76
AERONAUTICAL TECHNOLOGY – AIRCRAFT SYSTEMS SYNTHESIS

6%	940	6.2

AMRDL MAJOR TECHNICAL OBJECTIVES

EVALUATE ADVANCED AIR VEHICLE AND SUBSYSTEM CONCEPTS FOR OFFICIAL ARMY REQUIREMENTS.

ANALYZE ARMY AVIATION R&D PROGRAMS TO INSURE PROPER EMPHASIS AND TIMELINES OF TECHNOLOGY-BASE DEVELOPMENT.

DEVELOP ORDERLY PLANNING AND SYSTEMATIC PROGRAMMING FOR ARMY AVIATION R&D.

IDENTIFY ADVANCED AIRCRAFT CONCEPTS OF HIGH POTENTIAL APPLICABILITY TO ARYM AVAIATION REQUIREMENTS AND ASSESS IMPACT OF TECHNO–LOGICAL ADVANCES.

CONDUCT DESIGN, PERFORMANCE AND RISK STUDIES OF ADVANCED AIRCRAFT CONCEPTS.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES
IMPROVE THE MATERIEL ACQUISITION PROCESS
REDUCE THE COST OF ARMY WEAPONS SYSTEMS
IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF MAIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY
IMPROVE AIRCRAFT PROPULSION SYSTEMS
IMPROVE AIRCRAFT NIGHT OPERATION
EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS
INCREASE AIRCRAFT PERFORMANCE

Figure B-7. Aircraft Systems Synthesis R&D program flow diagram.

PROJECTS

% AND AMOUNT (IN THOUSANDS) OF FUNDS DEVOTED TO THIS TECHNOLOGY FOR FY 75

1F263213DB38
ROTOR SYSTEM RESEARCH AIRCRAFT

100%	927	6.3

1F263212DB74
TILT ROTOR AIRCRAFT

100%	3000	6.3

1F263211D157
ADVANCED HELICOPTER DEVELOPMENT

68%	1636	6.3

AMRDL MAJOR TECHNICAL OBJECTIVES

DEMONSTRATE FEASIBILITY AND EVALUATE PERFORMANCE OF ADVANCING BLADE CONCEPT ROTOR SYSTEM.

DEVELOP HYDROFLUIDIC SYSTEM TECHNOLOGY AND APPLICATION TO ARMY AIRCRAFT.

DEVELOP AIRCRAFT TO PROVIDE RESEARCH CAPABILITY THAT CANNOT BE DUPLICATED ON THE GROUND, TO TEST NEW ROTOR CONCEPTS, AND VERIFY SUPPORTING TECHNOLOGY BY DEMONSTRATION.

DEVELOP AN IN-FLIGHT SIMULATOR CAPABILITY FOR PRELIMINARY EVALUATION OF NEW CONCEPTS FOR IMPROVED CONTROLLABILITY AND TO VALIDATE GROUND BASED SIMULATORS.

AMC MBO AIRMOBILITY R&D GOALS

IMPROVE THE READINESS OF ARMY COMBAT FORCES
IMPROVE THE MATERIEL ACQUISITION PROCESS
REDUCE THE COST OF ARMY WEAPONS SYSTEMS
IMPROVE THE RELATIONSHIP OF AMC'S R&D EFFORTS TO AREAS OF MAIN CONCERN TO THE ARMY

MAJOR AIRMOBILITY R&D THRUSTS

IMPROVE SURVIVABILITY AND SAFETY
IMPROVE AIRCRAFT PROPULSION SYSTEMS
IMPROVE AIRCRAFT NIGHT OPERATION
EFFECT COST REDUCTION AND DECREASE LIFE CYCLE COSTS
INCREASE AIRCRAFT PERFORMANCE

Figure B-8. Advanced Technology Demonstration R&D program flow diagram.

APPENDIX C
BIBLIOGRAPHY OF PUBLICATIONS AND PRESENTATIONS IN FY 75

PAPERS AND PRESENTATIONS

Adams, Richard I., "An R&D Approach to the Solution of Helicopter Icing Problems," presented at the Rotary Wing Icing Symposium, Edwards AFB, CA, Jun 1974.

Austin, E.E., "Rotorcraft Flight Simulation A Problem in the Solution of A Large Set of Non-Linear Differential Equations," presented at US Army Numerical Analysis Conference, St. Louis, MO, Feb 1975.

Bailey, F.R.; and Ballhaus, W.F., "Comparisons of Computed and Experimental Pressures for Transonic Flows About Isolated Wings and Wing-Fuselage Configurations, Mar 1975.

Bailey, F.R.; and Ballhaus, W.F., "Finite Difference Solutions for Transonic Flows about Wings and Wing-Cylinder Configurations," presented at the NASA Conference on Aerodynamic Analyses Requiring Advanced Computers, Langley Research Center, 4-6 Mar 1975.

Ballhaus, W.F.; Magnus, R.; and Yoshihara, H., "Some Examples of Unsteady Transonic Flows Over Airfoils," Symposium on Unsteady Aerodynamics, Mar 1975.

Ballhaus, W.F.; Magnus, R.; and Yoshihara, H., "Some Finite Difference Examples of Unsteady Planar Flows Over the NACA 64A-410 Airfoil at M_∞ = 0.72," presented at Unsteady Aerodynamics Conference, Tucson, AZ, Mar 1975.

Balliett, CPT T.D., Article for ASME Gas Turbine Division 1975 Annual Report, Oct 1974.

Balliett, CPT T.D.; and Langworthy, R.A., "Importance of Future Aircraft Propulsion Systems," article for Army R&D, Mar-Apr 1975.

Beam, Richard M.; and Ballhaus, William F., "Numerical Integration of the Small-Disturbance Potential and Euler Equations for Unsteady Transonic Flow," Mar 1975.

Beam, Richard; and Ballhaus, William F., "Unsteady Transonic Flow by Numerical Integration of the Small Perturbation and Euler Equations," presented at the NASA Conference on Aerodynamic Analyses Requiring Advanced Computers, Langley Research Center, 4-6 Mar 1975.

Bingham, Gene J.; and Noonan, Kevin W., "An Analytical & Experimental Evaluation of Airfoil Sections for Helicopter Rotor Application," presented at AHS National Symposium on Helicopter Aerodynamic Efficiency, Hartford, CO, 6-7 Mar 1975.

Bratt, Howard M., "A Task Accomplishment Approach to Operational Life Cycle Cost Estimating," abstract of paper proposed for the 35th Military Operations Research Symposium (MORS), US Naval Academy, Annapolis, MD, to be held in Jul 1975.

Bratt, Howard M., "Aircraft R&M Simulation (ARMS) Model," presented at the 1975 Army Numerical Analysis and Computers Conference, US Army Troop Support Command, St. Louis, MO, Feb 1975.

Bratt, Howard M., "Can Cannibalization Improve Aircraft Availability?," abstract of paper proposed for the Tenth International Logistics Symposium, Lake Buena Vista, FL, to be held in Aug 1975.

Bratt, Howard M., "Homeostatic Criteria for Assessment of the Morphological State of Large Scale Hybrid Analytical-Simulation Computer Models," presented at the 21st Conference of Army Mathematicians, US Army White Sands Missile Range, El Paso, TX, May 1975.

Bratt, Howard M.; Collins, J.A.; and Hagan, B.T., "Helicopter Failure Modes and Corrective Actions," presented at the 1975 R&M Symposium, Washington, DC, Jan 1975.

Bratt, Howard M.; Collins, J.A.; and Hagan, B.T., "The Failure-Experience Matrix–A Useful Design Tool," abstract of paper proposed for the American Society of Mechanical Engineers (ASME) Failure Prevention and Reliability Conference, Washington, DC, to be held in Sep 1975.

Caradonna, Francis X; and Isom, Morris P., "Numerical Calculation of Unsteady Transonic Potential Flow Over Helicopter Rotor Blades," AIAA Paper No. 75-168, 20-22 Jan 1975.

Condon, Gregory W., "Rotor Systems Research Aircraft (RSRA) Requirements for, and Contributions to, Rotorcraft State Estimation and Parameter Identification," presented at the AGARD Flight Mechanics Panel Specialists Meeting on "Methods for Aircraft State and Parameter Identification," Hampton, VA, 5-8 Nov 1974.

Dodd, R.G.; and Balliett, CPT T.D., "Reducing Combustor Emission Levels," article for Vertiflite, Jul-Aug 1974.

Due, H.F., Jr.; Easterling, A.E.; and Rogo, C., "Cascade Research on a Small, Axial, High-Work, Cooled Turbine," presented at the 20th Annual International Gas Turbine Conference, 2-5 Mar 1975, ASME Paper 75-GT-62.

Falarski, Michael D.; Aiken, Thomas N.; Aoyagi, Kiyoshi; and Koenig, David G., "Comparison of the Acoustic Characteristics of Large-Scale Models of Several Propulsive-Lift Concepts," 21-23 Oct 1974, AIAA Paper No. 74-1094.

Foye, Raymond L., "Composites in Helicopter Fuselage Structures," Second Air Force Conference on Fibrous Composites in Flight Vehicle Design, Dayton, OH, May 1974.

Foye, Raymond L., "Structures and Materials Review," NASA/Army/Industry Rotorcraft Symposium, Langley Research Center, 19-21 Nov 1974.

Furgurson, R.G., "Advanced Engine Controls and Accessories for Helicopter Application," 31st Annual Forum of the AHS, Washington, DC, May 1975.

Givens, E.R., "Power Transfer and Engine Oil Monitors," presented at Coordination of Advanced Technology (Tri-Service), Trenton, NJ, Mar 1975.

Givens, E.R.; DeBruyne, N.A.; and Folenta, D.J., "Design and Development of a Free Planet Transmission," 31st Annual Forum of the AHS, Washington, DC, May 1975.

Hammond, C.E., "Aeroelastic Consideration in Wind Turbine Design," seminar presented at University of Texas, Austin, Tex, 28 Jan 1975.

Hammond, C.E., "An Application of Floquet Theory to Prediction of Mechanical Instability," Published in the Journal of the AHS, Oct 1974.

Hammond, C.E., "Helicopter Ground Resonance Analysis in Light of Army Requirements," presented at the Ninth Army Science Conference, West Point, NY, 18-21 Jun 1974.

Hammond, C.E., "Overview of Langley Research Center Rotor Dynamics Research," Aerospace Flutter and Dynamics Council Meeting, Williamsburg, VA, 24 Oct 1974.

Hammond, C.E., "Rotorcraft Aeroelastic and Dynamics Research at Langley Research Center," NASA/Army/Industry Symposium on Rotorcraft, Langley Research Center, 19-21 Nov 1974.

Hammond, C.E.; Runyan, H.L.; and Mason, J.P., "Application of Unsteady Lifting Surface Theory to Propellers in Forward Flight," presented at AIAA/ASME/SAE 15th Structures, Structural Dynamics and Materials Conference Las Vegas, NEV, 17-19 Apr 1974.

Hosier, Robert, "Langley Basic Research Review Document for 1974," presented at OAST Basic Research Review, 8 May 1974.

Hosier, Robert N.; Pegg, Robert J.; and Maglieri, Domenic J., "Joint Army/NASA Rotating Blade Acoustic Research Program at Langley Research Center," presented at NASA/Army/Industry Symposium on Rotorcraft, Langley Research Center, 19-21 Nov 1974.

Hurdle, Patrick M.; Meecham, W.C.; and Hodder, Brent K., "Investigation of the Aerodynamic Noise Generating Region of a Jet Engine by Means of the Simple Source/Fluid Dilatation Model," published in the Journal of the Acoustical Society of America, Dec 1974.

Hwang, John D., "Some Operations Research Activities of USAAMRDL," presented at The Army Research Office Operation Research Theme Review, University of Florida, Gainsville, FLA, Nov 1974.

Immen, F.H., "Apportionment Review, Army Air Mobility System Structures Technology – FY1976," presented at DOD Apportionment Review, Boston, MA, Apr 1975.

Immen, F.H., "Army Air Mobility Outlook for Structures 1980-2000," presented at JT ARMY/NASA meeting – The Outlook for Aeronautics 1980-2000, Washington, DC, Nov 1974.

Immen, F.H., "In Service Evaluation of Advanced Composites," presented at JT NASA/AF Seminar, Advanced Composites – An Assessment of the Future, Washington, DC, Jun 1975.

Kelley, Henry L, "Helicopter Stability Control, and Flying Qualities Program," presented at Langley Research Center Monthly Technical Symposium, 10 Jul 1974.

Kodani, H. Mike, "A Convergence Analysis of Iterative Techniques for Solving Linear Systems of Equations," presented at the 1975 Army Numerical Analysis Conference, St. Louis, MO, Feb 1975.

Langworthy, R.A., "Aircraft Propulsion Research and Development," presented at West Point, NY, Apr 1975.

Letchworth, LTC Robert, "Rotor Systems Research Aircraft (RSRA)," AGARD 46th Flight Mechanics Panel Symposium on "Flight/Ground Testing Facilities Correlations," ONERA – Mondane Center, France, 16-19 Jun 1975.

Levine, S.R.; Lowell, C.E.; and Grisaffe, S.J., "Environmental Effects and Surface Protection of High Temperature Alloys: A Review of NASA-Lewis Programs," presented at Navy Conference on Gas Turbine Materials, Castine, ME, 24 Jul 1974.

Levine, Stanley R.; and Seigle, L., "Kinetics of Pack Aluminization," presented at American Ceramic Society 77th Annual Meeting & Exposition, Washington, D.C., 3-8 May 1975.

McCroskey, W.J., "Recent Developments in Dynamic Stall," presented at the Symposium on Unsteady Aerodynamics, Tucson, AZ, 18-20 Mar 1975.

Mirick, P.H.; and Blackwell, R.H., "Effect of Blade Design Parameters on Helicopter Stall Boundaries," presented AHS Meeting, May 1974.

Mirick, P.H.; Carlson, R.G.; Black, R.H.; and Commerford, G.L., "Dynamic Stall Modeling and Correlation with Experimental Data on Airfoils and Rotors," presented at Specialist Meeting on Rotorcraft Dynamics, Feb 1974.

Mirick, P.H.; and Tarzanin, F.J., "Control Load Envelope Shaping By Live Twist," presented at Specialist Meeting on Rotorcraft Dynamics, Feb 1974.

Morrow, H.L., et al, "Annual Tri-Service Propulsion Program Review," Ft. Eustis, VA, Jun 1975.

Morrow, H.L., et al. "Army Propulsion Program Review," presentation to DDR&E, Ft. Eustis, VA, May 1975.

Nash, John F.; Carr, Lawrence W.; and Singleton, Robert E., "Unsteady Turbulent Boundary Layers in Two-Dimensional Incompressible Flow," presented as Paper 73-650 at the AIAA 6th Fluid and Plasma Dynamics Conference, Palm Springs, CA, Feb 1975.

Nettles, W.E., "Application of Advanced Numerical Analysis Techniques to the Determination of Helicopter Tail Rotor/Fuselage System Dynamic Aeroelastic Stability Characteristics," presented at US Army Numerical Analysis Conference, St. Louis, MO, Feb 1975.

Nolan, William J.; and Carr, R.W., "Improved Restraint for US Army Aircrewmen," presented at the Third International Conference on Occupant Protection, Troy, MI, Jul 1974.

Ormiston, Robert A., "Comparison of Several Methods for Predicting Loads on a Hypothetical Helicopter Rotor," printed in the Journal of the American Helicopter Society, Oct 1974.

Ormiston, Robert A., "Dynamic Response of Wind Turbine Rotor Systems," presented at the 31st Annual National Forum of the American Helicopter Society, Washington, DC, May 1975.

Ormiston, R.A.; and Bousman, W.G., "A Study of Stall-Induced Flap-Lag Instability of Hingeless Rotors," presented at the 29th Annual National Forum of the American Helicopter Society, May 1973, printed Jan 1975.

Rabbott, John P.; and Stroub, Robert H., "Wasted Fuel – Another Reason for Drag Reduction," presented at the American Helicopter Symposium on Helicopter Aerodynamic Efficiency, East Hartford, CN, 6-7 Mar 1975.

Raitch, F.A., "Summary of Antitorque Devices Other Than Tail Rotors," presented at AHS – Northeast Region Meeting, Mar 1975.

Runyan, H.L.; and Hammond, C.E., "Vibration, Unsteady Loads and Flutter," Lectures presented at University of Colorado Short Course on Theory and Design of Windmills, 10-21 Jun 1974.

Schmitz, Fredric H.; and Vause, C. Rande, "A Simple, Near-Optimal Takeoff Control Policy for a Heavily Loaded Helicopter Operating from a Restricted Area," presented at AIAA Mechanics and Control of Flight Conference, 5-9 Aug 1974, AIAA Paper No. 74-812.

Shostak, John; and Ladd, Joe D., "Radar Cross Section Reduction of Aircraft Rotor Blades and Propellers," abstract of paper proposed for AFAL/AFML Radar Camouflage Symposium, Wright-Patterson AFB, OH, to be held in Oct 1975.

Simon, Duane R.; and Savage, Jimmie C., "Army Preliminary Evaluation of the HLH ATC Demonstrator Fly-By-Wire Flight Control System," presented at the 31st Annual National Forum of the American Helicopter Society, Washington, DC, May 1975.

Singley, George T., Jr., "Army V/STOL Technology Review," presented at the SAE Aerospace Engineering & Manufacturing Meeting, Has V/STOL Come of Age? Session, San Diego, CA, 30 Sep – 3 Oct 1974.

Singley, George T., III, "Crashworthy Seat & Restraint System for Army Aircraft," to be published in AMC Safety Digest, prepared Jun 1974.

Singley, George T., III, "MIL-STD 1290 (AV), Light Fixed- And Rotary-Wing Aircraft Crashworthiness," published in May-Jun 1975 edition of Army R&D Magazine.

Soderman, Paul T.; and Noble, Stephen C., "A Directional Microphone Array for Acoustic Studies of Wind Tunnel Models," presented at AIAA 8th Aerodynamic Testing Conference, 8-10 Jul 1974, AIAA Paper No. 74-640.

Tomaine, Robert L., "Helicopter Parameter Identification Utilizing an Advanced Statistical Algorithm," presented at 1975 Army Numerical Analysis Conference, St. Louis, MO, 11-12 Feb 1975.

White, William F., Jr., "Aeroelastic Stability of Hingeless Rotors in Hover and Forward Flight," presented at Langley Research Center Monthly Technical Symposium, 10 Jul 1974.

White, William F., Jr., "Hingeless Rotor Stability Analyses," presented at Aerospace Flutter and Dynamics Council Meeting, Williamsburg, VA, 24 Oct 1974.

White, William F., Jr., "Importance of Helicopter Dynamics to the Mathematical Model of the Helicopter," presented at AGARD Flight Mechanics Panel Specialists Meeting on "Methods for Aircraft State and Parameter Identification," at Langley Research Center, 5-8 Nov 1974.

White, William F., Jr.; and Malatino, Raymond E., "A Numerical Method for Determining the Natural Vibration Characteristics of Hingeless Rotors," presented at 1975 Army Numerical Analysis Conference, St. Louis, MO, 11-12 Feb 1975.

Wilson, John C., "Rotorcraft Low-Speed Download Drag Definition and its Reduction," presented at the 31st National Forum of the AHS, Washington, DC, 13-15 May 1975.

Young, Warren G., Jr., "Joint Army/NASA Aerodynamics Research Program at Langley Research Center," presented at NASA/Army/Industry Symposium on Rotorcraft, Langley Research Center, 19-21 Nov 1974.

AMRDL REPORTS

Advanced Systems Research Office, AMRDL, "Army Aviation RDT&E Plan," Jun 1974.

Advanced Systems Research Office, AMRDL, "Army Aviation RDT&E Plan-Executive Summary," Jun 1974.

Advanced Systems Research Office, AMRDL, "Laboratory Project Selection Process," Jul 1974.

Advanced Systems Research Office, AMRDL, "Single Program Element Funding Semi-annual Technical Report," Dec 1974.

Advanced Systems Research Office, AMRDL, "Summary of Risk Analysis," Jan 1975.

Advanced Systems Research Office, AMRDL, "An Analysis of Root Moment in Rotor Blades," Mar 1975.

Advanced Systems Research Office, AMRDL, "Mathematical Applications to Problems in Aeronautics," May 1975.

Advanced Systems Research Office, AMRDL, "Single Project Funding – Single Program Element Funding, Final FY75/Initial FY76 Technical Report," Jun 1975.

Bill*, Robert C., "Some Metal-Graphite and Metal-Ceramic Composites for use as High-Energy Brake Lining Materials," NASA TN D-7756, Aug 1974.

Bill*, Robert C.; and Wisander, Donald W., "Surface Recrystallization Theory of the Wear of Copper in Liquid Methane," NASA TN D-7840, Dec 1974.

Bingham*, Gene J., "An Analytical Evaluation of Airfoil Sections for Helicopter Rotor Applications," NASA TN D-7796, Feb 1975.

Brown*, Thomas J.; Brown, Christine G.; and Hardin, Jay C., "Program for the Analysis of Time Series," NASA TM X-2988, Sep 1974.

Bryant*, Timothy D.; and Soloman, Daniel W., Jr., "Radio-Controlled, Sound-Operated Switch," B74-10143, Sep 1974.

Civinskas*, Kestutis C., "A Comparison of Optimum JP and LH_2 Turbofan Engines Designed for Two Subsonic Transport Missions," NASA TM X-71622, Oct 1974.

DiCarlo*, Daniel J.; Kelley*, Henry L.; and Yenni, Kenneth R., "An Exploratory Flight Investigation of Helicopter Sling-Load Placements Using a Closed-Circuit Television as a Pilot Aid," NASA TN D-7776, Nov 1974.

Frick*, Juanita K.; and Johnson*, Wayne, "Optimal Control Theory Investigation of Proprotor/Wing Response to Vertical Gust," NASA-Ames TM X-62, 384, Sep 1974.

*Denotes AMRDL employee

Galvas*, Michael R., "A Compressor Designed for the Energy Research and Development Agency Automotive Gas Turbine Program," NASA TM X-71719, May 1975.

Galvas*, Michael R., "Computer Program for Predicting Off-Design Performance of Centrifugal Compressors," B74-10067, Aug 1974.

Greenbaum*, Anne; Baker*, Donald J.; and Davis, John G., Jr., "A Computer Program for Plotting Stress – Strain Data from Compression, Tension, and Torsion Tests of Materials," NASA TM X-3091, Nov 1974.

Greszczuk, L.B.; and Chao, H., "Investigation of Brittle Fractures in Graphite-Epoxy Composites Subjected to Impact," USAAMRDL TR 75-15, May 1975.

Haas*, Jeffrey E.; and Kofskey, Milton G., "Cold-Air Performance of a 12.766-Centimeter-Tip-Diameter Axial-Flow Cooled Turbine. I – Design and Performance of a Solid Blade Configuration, NASA TN D-7881, Jan 1975.

Hoad*, Danny R., "Longitudinal Aerodynamic Characteristics of an Externally Blown Flap Powered-Lift Model with Several Propulsive System Simulators," NASA TN D-7670, Sep 1974.

Hodder*, Brent K., "The Effects of Forward Speed on Fan Inlet Turbulence and Its Relation to Tone Noise Generation," NASA-Ames TM X-62, 381, Aug 1974.

Hodges*, D.H.; and Dowell, E.H., "Nonlinear Equations of Motion for the Elastic Bending and Torsion of Twisted Nonuniform Rotor Blades," NASA-Ames TN D-7818, Dec 1974.

Hosier*, Robert N.; and Ramakrishnan, Ramani, "Helicopter Rotor Rotational Noise Predictions Based on Measured High-Frequency Blade Loads," NASA TN D-7624, Dec 1974.

Isom, Morris P., "Unsteady Subsonic and Transonic Potential Flow Over Helicopter Rotor Blades," NASA-Ames CR-2463, Oct 1974.

Johnson*, Wayne, "Analytical Model for Tilting Proprotor Aircraft Dynamics, Including Blade Torsion and Coupled Bending Modes, and Conversion Mode Operation," NASA-Ames TM X-62, 369, Aug 1974.

Johnson*, Wayne, "Comparison of Three Methods for Calculation of Helicopter Rotor Blade Loading and Stresses Due To Stall," NASA-Ames TN D-7833, Nov 1974.

Johnson*, Wayne, "Perturbation Solutions for the Influence of Forward Flight on Helicopter Rotor Flapping Stability," NASA-Ames TM X-62, 361, Aug 1974.

Johnson*, Wayne, and Biggers, James C, "Shake Test of Rotor Test Apparatus in the 40- by 80-Foot Wind Tunnel," NASA-Ames TM X-62, 418, Feb 1975.

Levine*, Stanley R.; and Caves, Robert M., "Thermodynamics and Kinetics of Pack Aluminide Coating Formation on IN-100," Vol. 121, No. 8, Journal of the Electrochemical Society, 8 Aug 1974.

Loewenthal*' Stuart H.; Parker, Richard J.; and Zaretsky, Erwin V., "Correlation of Elastohydrodynamic Film Thickness Measurements for Fluorocarbon, Type II Ester, and Polyphenyl Ether Lubricants," NASA TN D-7825, Nov 1974.

Mineck*, Raymond E.; and Carter, Arthur, W., "Effect of Ground Proximity on the Longitudinal Aerodynamic Characteristics of an Aspect-Ratio-1 Wing with and without Wing-tip Blowing," NASA TM X-3048, Jul 1974.

Moore*, Frederick L; Roberts, David A.; and Lina, Lindsay J., "Simulation Study of the Effectiveness of Thrust Vectoring Using the Harrier Aircraft in Air Combat (U)," NASA TM X-3118, Dec 1974, SECRET.

Mularz*, Edward J., "Flow Characteristics of Various Swirl-Can Module Designs," NASA TM X-3236, Jun 1975.

Mularz*, Edward J.; Wear, Jerrold D.; and Verbulecz, Peter W., "Exhaust Pollutant Emissions from Swirl-Can Combustor Module Arrays at Parametric Test Conditions," NASA TM X-3237, Jun 1975.

Mularz*, Edward J.; Wear, Jerrold D.; and Verbulecz, Peter W., "Pollution Emissions from Single Swirl-Can Combustor Modules at Parametric Test Conditions," NASA TM X-3167, Jan 1975.

Ormiston*, Robert A., "Techniques for Improving the Stability of Soft Inplane Hingeless Rotors," NASA-Ames TM X-62, 390, Oct 1974.

Parlett, Lysle P.; Emerling, Sandy J.; and Phelps*, Arthur E. III, "Free-Flight Investigation of the Stability and Control Characteristics of a STOL Model With an Externally Blown Jet Flap," NASA TN D-7411, Apr 1974.

Peters*, David A., "An Approximate Closed-Form Solution for Lead-Lag Damping of Rotor Blades in Hover," NASA-Ames TM X-62, 425, Apr 1975.

Peters*, David A.; and Ormiston*, Robert A., "Flapping Response Characteristics of Hingeless Rotor Blades by a Generalized Harmonic Balance Method," NASA-Ames TN D-7856, Feb 1975.

Roderick*, G.L.; Everett*, R. A.; and Crews, J. H. Jr., "Debond Propagation in Composite Reinforced Metals," NASA TM X-71948, Feb 1974.

Schumann, Lawrence F.; Kofskey, Milton G.; and Katsanis, Theodore, "Aerodynamic Design of a Free Power Turbine for a 75KW Gas Turbine Automotive Engine," NASA TM X-71714, Apr 1975.

Shaw*, Craig S.; and Wilson*, John C., "Control Vane for Engine Exhaust Flow," B74-10138, Sep 1974.

Shinn*, Ronald A.; and Wheatley*, John B., "Preliminary Systems Design Engineering (PSDE) for a Small Tactical Aerial Reconnaissance Systems-Visual (STARS-V)," Jun 1974.

Shinn*, Ronald A., "Preliminary Systems Design Engineering (PSDE) for an Advanced Scout Helicopter (ASH) (U)," Aug 1974, CONFIDENTIAL.

Smith, Charles C., Jr.; Phelps*, Arthur E., III; and Copeland, W. Latham, "Wind-Tunnel Investigation of a Large-Scale Semispan Model with an Unswept Wing and an Upper-Surface Blown Jet Flap," NASA TN D-7526, Feb 1974.

USAAMRDL, "A Technical Assessment of U.S. Army Flight Simulation Capability and Requirements for Aviation Research and Development," DRAFT.

Van Fossen*, G. James, Jr., "Design of Experiments for Measuring Heat-Transfer Coefficients with a Lumped-Parameter Calorimeter," NASA TN D-7857, Jan 1975.

Van Fossen*, G. James, Jr., "Surface Heat-Transfer Coefficients of Pin-Finned Cylinders," NASA TM X-3173, Jan 1975.

Van Fossen*, G. James, Jr., "External Fins and Ejector Action for Reducing the Infrared Emission of Engine Exhaust Ducting," NASA TM X-3242, Jun 1975.

Wilson*, John C. "Flight Investigation of a Temperature Reducing Modification for the AH-1G Infrared Suppressor Exhaust Kit (U)," NASA TM X-3131, Dec 1974, CONFIDENTIAL.

Wilson*, John C., "Flight Investigation of Temperature Reduction Modifications to the OH-58A Infrared Suppressor Exhaust Kits (U)," NASA TM X-3081, Jul 1974, CONFIDENTIAL.

Wilson*, John C.; and Mineck*, Raymond E., "Wind-Tunnel Investigation of a Simulated Gunship Helicopter Engine-Exhaust – Windstream Interaction," NASA TM X-3161, Dec 1974.

Wilson*, John C.; and Mineck*, Raymond E., "Wind-Tunnel Investigation of Helicopter-Rotor Wake Effects on Three Helicopter Fuselage Models," NASA TM X-3185, Mar 1975.

Yeager*, William T. Jr.; Young*, Warren H. Jr.; and Mantay*, Wayne R., "A Wind-Tunnel Investigation of Parameters Affecting Helicopter Directional Control at Low Speeds in Ground Effect," NASA TN D-7694, Nov 1974.

CONTRACT REPORTS

Adamczyk, John J., "The Passage of an Infinite Swept Airfoil Through an Oblique Gust," United Aircraft Research Laboratories, NASA CR-2395, May 1974.

Akeley, C.R.,; and Carson, G.W.; "Fan-in Fuselage Advanced Antitorque System," Kaman Aerospace Corp., USAAMRDL-TR-74-89, Fort Eustis, VA, Nov 1974.

Bellinger, E.D.; Patrick, W.P.; Greenwald, L.E.; and Landgrebe, A.J., "Experimental Investigation of the Effects of Helicopter Rotor Design Parameters on Forward Flight Stall Characteristics," United Aircraft Research Laboratories, USAAMRDL-TR-74-1, Fort Eustis, VA, Apr 1974.

Blackwell, R.H.; and Commerford, G.L., "Investigation of the Effects of Blade Structural Design Parameters on Helicopter Stall Boundaries," Sikorsky Aircraft Div., USAAMRDL-TR-74-25 Fort Eustis, VA, May 1974.

Briczinski, Stanley J.; and Cooper, Dean E., "Flight Investigation of Rotor/Vehicle State Feedback," Sikorsky Aircraft Division, NASA CR-132546, Langley Directorate, VA, Nov 1974.

Cotton, L.S., "Three Axis Fluidic/Electronic Automatic Flight Control System Flight Test Report," Sikorsky Aircraft Div., USAAMRDL-TR-74-62, Fort Eustis, VA, Aug 1974.

Davis J.M.; Bennett, R.L.; and Blankenship, B.L.; "Rotorcraft Flight Simulation With Aeroelastic Rotor and Improved Aerodynamic Representation," Vol I & II, Bell Helicopter Co., USAAMRDL-TR 74-10 A through C, Fort Eustis, VA, Jun 1974.

Dowell, E.H., "A Variational Rayleigh-Ritz Modal Approach for Non-Uniform Twisted Rotor Blades Undergoing Large Bending and Torsional Motion," AMS Report No. 1193, Princeton University, Contract NAS 2-7615, Nov 1974.

Dowell, E.H.; and Traybar, J., "An Experimental Study of the Nonlinear Stiffness of a Rotor Blade Undergoing Flap, Lag and Twist Deformations," AMS Report No. 1194, Princeton University, Contract NAS 2-7615, Jan 1975.

Freeman, E.D.; and Bennett, R.L., "Application of Rotorcraft Flight Simulation Program (C-81) to Predict Rotor Performance and Bending Moments for a Model Four-Bladed Articulated Rotor System Bell Helicopter Co.," USAAMRDL-TR 74-70, Fort Eustis, Va, Nov 1974.

Friedmann, Peretz; and Silverthorn, Louis J., "Aeroelastic Stability of Coupled Flap-Lag Motion of Hingeless Helicopter Blades at Arbitrary Advance Ratios," Mechanics and Structures Dept., School of Engineering and and Applied Science, University of California, Los Angeles, CA, NASA CR-132431, Feb 1974.

Griffin, R.N., "Development of High Temperature Resistant Graphite Fiber Coupling Agents," General Electric Company, NASA CR-134725, Lewis Directorate, Feb 1975.

Kesler, D.F.; Murakoski, A.Y.; and Sinacori, J.B., "Flight Simulation of the Model 347 Advanced Tandem Rotor Helicopter," Northrup Corp. Aircraft Div., USAAMRDL-TR-74-21, Fort Eustis, VA, Nov 1974.

Lee, Charles D.; and White, James A., "Investigation of the Effect of Hub Support Parameters on Two-Bladed Rotor Oscillatory Loads," Bell Helicopter Company, NASA CR-132435, May 1974.

Metzgn, R.F.; Plabs, A.; Meier, R.C.; and Berman, A., "Development of A Method for the Analysis of Improved Helicopter Design Criteria," Kaman Aerospace Corp., USAAMRDL-TR-74-30, Fort Eustis, VA, Jul 1974.

Molusis, John A., "Analytical Study to Define A Helicopter Stability Derivative Extraction Method Volume I – Final Report," Sikorsky Aircraft Division, NASA CR-132371 – Volume I and CR-132372 – Volume II, Langley Directorate, May 1974.

Nash, J.F.; and Patel, V.C., "Calculations of Unsteady Turbulent Boundary Layers with Flow Reversal," Sybucon Inc., NAS2-7724, Nov 1974.

Niebanck, C.F., "Model Rotor Test Data for Verification of Blade Response and Rotor Performance Calculations," Sikorsky Aircraft Div., USAAMRDL-TR-74-29, Fort Eustis, VA, May 1974.

Ogren, H.D., "Hydrofluidic Yaw SAS Analysis Design and Development," Honeywell Inc., USAAMRDL-TR-74-7, Fort Eustis, VA, Mar 1974.

Ogren, H.; Sotanski, D.; and Genaw L., "Yaw Axis Stability Augmentation System Flight Test Report," Honeywell Inc., USAAMRDL-TR-74-39, Fort Eustis, VA, Jun 1974.

Schwendler, Robert G., "Improvements to the Sadsam Computer Program for Aeroelasticity Analysis," The MacNeal-Schwendler Corporation, NASA CR-132617, Langley Directorate, VA, Mar 1975.

Scruggs, R.M.; Nash, J.F.; and Singleton, R.E., "Analysis of Dynamic Stall Using Unsteady Boundary – Layer Theory," Scientific and Business Consultants, Inc., NASA CR-2462, Langley Directorate, Oct 1974.

Shamroth, S.J.; and Kreskovsky, J.P., "A Weak Interaction Study of the Viscous Flow about Oscillating Airfoils," United Aircraft Research Laboratories, NASA CR-132425, May 1974.

Shiembob, L.T., "Development of Abradable Gas Path Seals," Pratt & Whitney Aircraft, NASA CR-134689, Lewis Directorate, 1975.

Shipman, K.W., "Effect of Wake on the Performance and Stability Characteristics of Advanced Rotor System," Rochester Applied Science Associates, Inc., USAAMRDL-TR-74-45, Fort Eustis, VA, Sep 1974.

Tarzanin, F.J.; and Ranieri, J., "Investigation of the Effect of Torsional Natural Frequency on Stall-Induced Dynamic Loading," Boeing-Vertol Co., USAAMRDL-TR-73-94, Fort Eustis, VA, Feb 1974.

Ulitchny, M.G.; and Lucas, J.J., "Evaluation of Graphite Composite Materials for Bearingless Helicopter Rotor Application," Sikorsky Aircraft, NASA CR-132414, Jan 1974.

Van Gaasbeek, J.R., "An Investigation of High-G Maneuvers of the AH-1G Helicopter," Bell Helicopter Co., USAAMRDL-TR-74-18, Fort Eustis, VA, Apr 1974.

Wood, T.L.; Ford, D.G.; and Brigman, G.H., "Maneuver Criteria Evaluation Program," Bell Helicopter Co., USAAMRDL-TR-74-32, Fort Eustis, VA, May 1974.

Woodward, F.A.; Dvorak, F.A.; and Geller, E.W., "A Computer Program for Three-Dimensional Lifting Bodies in Subsonic Inviscid Flow," Flow Research Inc., USAAMRDL-TR-74-18, Fort Eustis, VA, Apr 1974.

Wright, Charles C.; Baker, Donald J.; Thurston, L.; and Clary, R., "Progress Report II of Cooperative Program for Design, Fabrication, and Testing of Graphite-Epoxy Composite Helicopter Shafting," Materials Engineering Division, Feltman Research Laboratory, TR-4688, Langley Directorate, Dec 1974.

APPENDIX D
LIST OF ABBREVIATIONS

AAH	Advanced Attack Helicopter
AALESS	Active Arm Load Stabilization System
AARL	Army Aeronautical Research Laboratory
ABC	Advancing Blade Concept
AFCS	Automatic Flight Control System
AI/BS	Active Isolation/Balance System
AGARD	Advisory Group for Aerospace Research and Development
AMC	(US) Army Materiel Command
AMMRC	(US) Army Materials and Mechanics Research Center
AMRDL	(US Army) Aviation Mobility Research and Development Laboratory
ARMCOM	(US Army) Armament Command
ARMS	Aircraft Reliability and Maintainability Simulation
ASAP	Army Scientific Advisory Panel
ASH	Advanced Scout Helicopter
ASRO	Advanced Systems Research Office
ATC	Advanced Technology Components
AVLABS	(US Army) Aviation Materiel Laboratories
AVSCOM	(US Army) Aviation Systems Command
BHC	Bell Helicopter Company
CAD–E	Computer Aided Design and Engineering
CTR	Controllable Twist Rotor
DA	Department of the Army
DAVI	Dynamic Anti-Resonant Vibration Isolator
DC	Direct Current
DCOPS	Deputy Chief of Staff for Operations and Plans
DOD	Department of Defense
ECOM	(US Army) Electronics Command
EEO	Equal Employment Opportunity
FORSCOM	(US Army) Forces Command
GRAM	Generalized Rotor Aeroelastic Model
HEI	High Explosive Incendiary
HEMP	High Explosive Multi-Purpose
HLH	Heavy Lift Helicopter
IAC	Institute for Advanced Computation
IFAMS	In-Flight Acoustic Measurement System
IOC	Initial Operational Capability
IR	Infrared
ITR	Integrated Test Rig
LLNO	Low Level Night Operation
LOA	Letter of Agreement
LTTAS	Light Tactical Transport Aircraft System
MAVS	Manned Aerial Vehicle for Surveillance

MBO	Management by Objectives
MICOM	(US Army) Missile Command
MIL	Man-In-Loop
MOU	Memorandum of Understanding
MWFCS	Mutli-Weapon Fire Control System
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structures Analysis
NATO	North Atlantic Treaty Organization
NOE	Nap-of-the-Earth
ONERA	Office National d' Etudes de Recherches Aerospatiales
ORSA	Operations Research Society of America
PE	Processing Elements
PM	Project/Product Manager
R&D	Research and Development
R&M	Reliability and Maintainability
RDM	Rotor Dynamics Model
RDT&E	Research, Development, Test, and Engineering
RFP	Request for Proposal
RIF	Reduction In Force
RIO	Return on Investment
RPV	Remotely Piloted Vehicle
RSRA	Rotor System Research Aircraft
RTA	Rotor Test Apparatus
SCR	Silicon Controlled Rectifiers
SCSC	Shallow-Cone Shaped-Charge
SHP	Shaft Horsepower
SOR	Successive Over-Relaxation
SPEF	Single Program Element Funding
SRIO	Systems Research Integration Office
SSOR	Symmetric Successive Over-Relaxation
STAGG	Small Turbine Advanced Gas Generator
STARS-V	Small Tactical Aerial Reconnaissance System–Visual
TDA	Tables of Distribution and Allowances
TILO	Technical Industrial Liaison Office
TIMS	The Institute of Management Sciences
TRADOC	(US Army) Training and Doctrine Command
TRADS	Transportation Research and Development Support
TRADSCOM	Transportation Research and Development Command
TRASTAN	Tail Rotor Aeroelastic Stability Analysis
TRECOM	Transportation Research and Engineering Command
TV	Television
USAF	United States Air Force
UTTAS	Utility Tactical Transport Aircraft System
VHLH	Very Heavy Lift Helicopter
V/STOL	Vertical/Short Takeoff and Landing
V/STOLAND	V/STOL Advanced Autopilot System